New Scientist

WEEKLY 9 December 2023

WHY AI NEEDS A BODY TO BECOME TRULY INTELLIGENT

AVOIDING SOCIETAL COLLAPSE: SOME LESSONS FROM HISTORY

THE BEST MUSIC TO PLAY AT PARTIES (SCIENTIFICALLY SPEAKING)

THE TRUTH ABOUT VAPING

It's reached epidemic proportions. How bad is it for you?

COP28 SPECIAL REPORT

Why 'loss and damage' matters

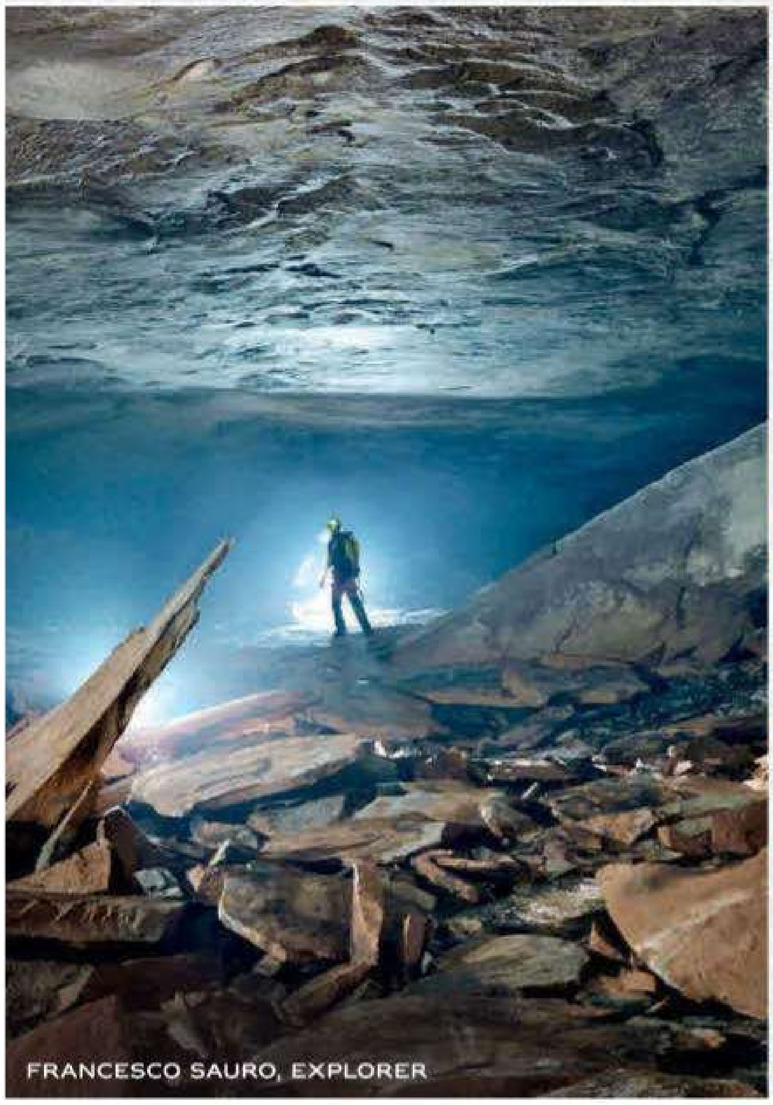
How we will know we've passed 1.5°C

Can positive tipping points speed climate action?

No3468 £6.95 CAN$9.99

ROLEX AND NATIONAL GEOGRAPHIC
PERPETUAL PLANET AMAZON EXPEDITION

DAWA YANGZUM SHERPA,
INTERNATIONAL
MOUNTAIN GUIDE



FRANCESCO SAURO, EXPLORER

CRISTIAN DONOSO, EXPLORER

GHISLAIN BARDOUT, EXPLORER

WHAT DO THEY SEEK?

Explorers, adventurers, scientists. Men and women who always broadened the horizons, for all humankind to share. Rolex was at their side when they reached the deepest point in the oceans, the highest summits of the Earth, the deepest jungles and both poles. But now that we know, more than ever, that our world has its limits, why do they continue to venture out there, again and again? Certainly not for kudos, accolades, or an ephemeral record. What they truly seek is to understand more intimately how complex and delicate our planet is, to document its change and how together, we can affect it for the better. So as long as they need it, we will be at their side. Because today, the real discovery is not so much about finding new lands. It's about looking with new eyes at the marvels of our planet, rekindling our sense of wonder, and acting to preserve our pale blue dot in the universe…

Doing our very best for a Perpetual Planet.

#Perpetual

OYSTER PERPETUAL
SUBMARINER DATE

ROLEX
Perpetual Planet Initiative

ROLEX

This week's issue

On the cover

32 The truth about vaping
It's reached epidemic proportions. How bad is it for you?

8 COP28 special report
Why 'loss and damage' matters
How we will know we've passed 1.5°C
Can positive tipping points speed climate action?

New Scientist
AVOIDING SOCIETAL COLLAPSE: SOME LESSONS FROM HISTORY
THE TRUTH ABOUT VAPING
It's reached epidemic proportions. How bad is it for you?
COP28 SPECIAL REPORT

Vol 260 No 3468
Cover image: Klaus Kremmerz

40 Why AI needs a body to become truly intelligent

36 Avoiding societal collapse: Some lessons from history

15 The best music to play at parties (scientifically speaking)

36 Features

> **"Societies become more resilient because they become more complex"**

News

12 Thrown out
Passing star could fling Earth past Pluto into the Oort cloud

14 Twin effect
Marmoset siblings swap brain cells in utero

18 Nutrient stash
Supercontinents helped life evolve on land by trapping soil

Views

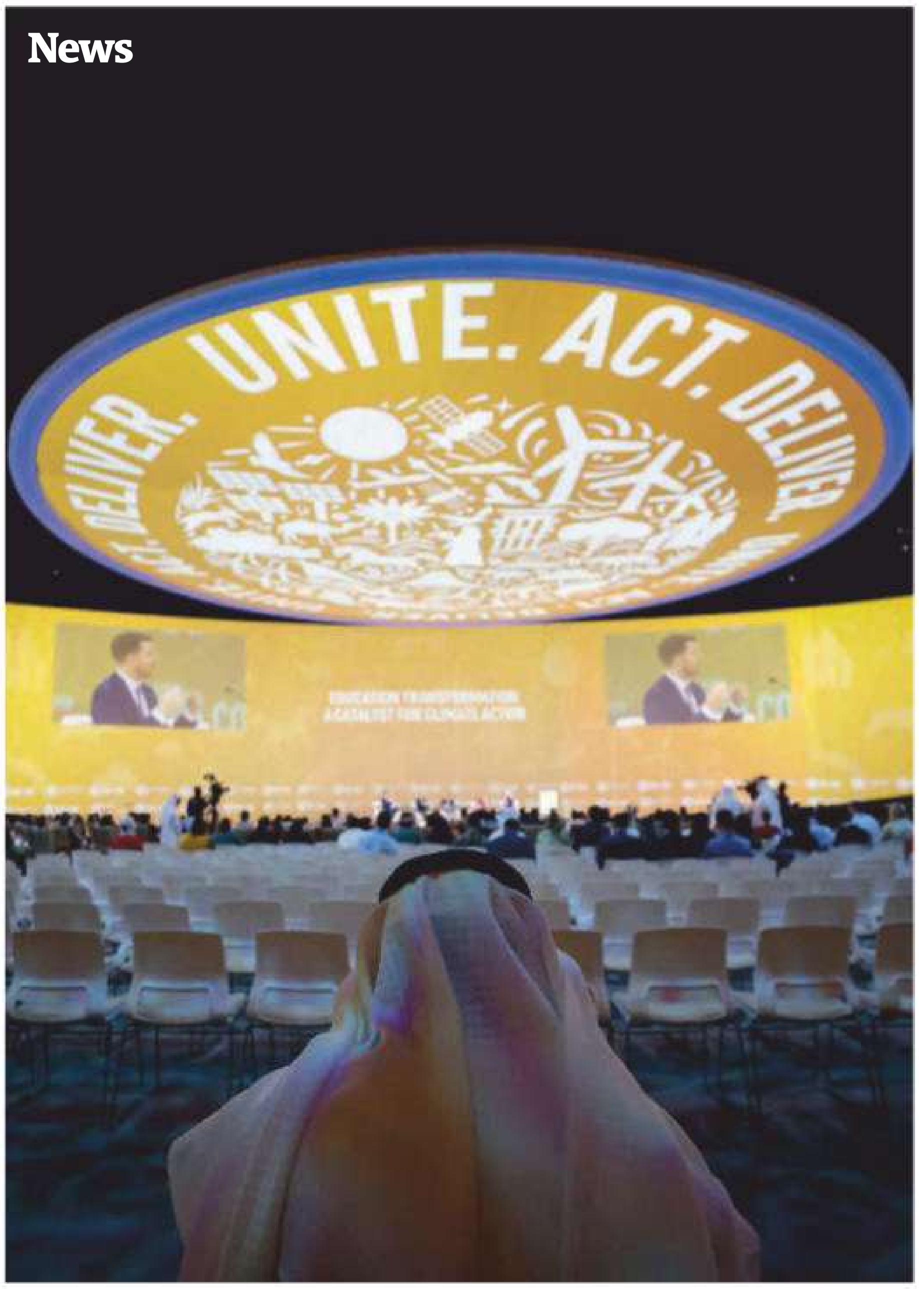
21 Comment
The US needs to do more to preserve its ancient sites, says Rachel Morgan

22 The columnist
Chanda Prescod-Weinstein on the Unruh effect

24 Aperture
Illuminating tropical forests

26 Letters
On the search for what makes us human

28 Culture
Music inspired by the acoustics of glacial caves



HOLLIE ADAMS/BLOOMBERG VIA GETTY IMAGES

8 Dubai deals The COP28 climate summit's key agreements so far

Features

32 Fog of uncertainty
Are fears over the health effects of vaping well-founded?

36 Heading for a fall
What to make of reports that Western civilisation is about to collapse

40 Embodied cognition
How "evolutionary robotics" can create the perfect body to enhance artificial intelligence

The back pages

44 Debunking gardening myths
Should you remove fallen leaves?

45 Puzzles
Try our crossword, quick quiz and logic puzzle

46 *Almost* the last word
As sound dissipates, what happens to its energy?

48 Feedback
Getting into gear and foaming at the mouth

48 Twisteddoodles for *New Scientist*
Picturing the lighter side of life

Elsewhere on New Scientist

Virtual event

The best of *New Scientist* 2023

Hear *New Scientist* journalists review the biggest stories of the year, reveal their favourite articles of the past 12 months and tell us what their hopes and fears are for science in 2024. This online, subscriber-only event is hosted by our deputy US editor Timothy Revell on 12 December at 6pm GMT.

newscientist.com/events

Tour

Rewilding in the Côa valley: Portugal

Discover unique, unspoiled landscapes in an area that is home to vultures, eagles, otters, wild horses, turtles and the Iberian wolf. Accompanied by Fernando Romão from Rewilding Portugal, you will hear how the natural rhythms of wildlife are being embraced to create more biodiverse habitats that support nature. This six-day tour starts on 29 April and costs £2895.

newscientist.com/tours

Podcast

Weekly

In this episode, the team are talking about the ongoing COP28, the most important climate summit since the 2015 Paris Agreement. They also reveal the possible consequences of another star visiting our solar system and find out how robotic laboratories and could be used to find materials to make better batteries and solar cells. Plus, dolphins use electric fields to hunt and navigate.

newscientist.com/nspod

BLUE NOMADS

Going wild See Sorraia horses on a tour in the Côa valley, Portugal

MARILYN SARGENT/BERKELEY LAB

Artificial chemistry Robots testing materials dreamed up by AI

Video

The music of cancer-treating plants

In 2019, composer and musician Helen Anahita Wilson was diagnosed with breast cancer. Her subsequent treatment became the creative spark for the work *Linea Naturalis*. She recorded the micro-electric fluctuations of plants used in anti-cancer treatments and chemotherapy, then turned them into a 45-minute soundscape.

youtube.com/newscientist

Newsletter

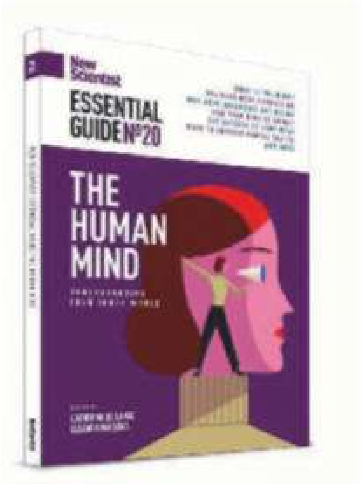
Health Check

Clare Wilson delves into the placebo effect. Some intriguing results show that its magnitude seems to depend on people's beliefs about the supposed treatment they are receiving and the context in which it is administered. For instance, larger pills can have a stronger placebo effect than small ones.

newscientist.com/health-check

Newsletter

> **"Larger pills have a stronger placebo effect than smaller ones"**



Essential guide

Your mind underpins your every experience and is integral to both the internal feeling of being "you" as well as how others perceive you. It is so familiar, yet extremely hard to pin down. Unravel the truth about your inner world with the latest *New Scientist Essential Guide*. Buy in print now.

shop.newscientist.com

UK Export Finance

Supporting
UK exporters with
GOVERNMENT-BACKED TRADE FINANCE

We've got the financial solutions to help you sell your products or services overseas. If you've got a viable export opportunity, our Export Finance Managers can help you take the next step.

WIN CONTRACTS **FULFIL ORDERS** **GET PAID**

ukexportfinance.gov.uk

The leader

An imperfect experiment

Different approaches to vaping regulation can show us how to make a smoke-free world

YOU have no doubt seen someone on the street surrounded by a sweet-smelling cloud. A vaper. Globally, this is becoming an increasingly familiar sight as more and more people take up the habit. The question on everyone's lips is, just how bad are these e-cigarettes for your health?

Answers are finally emerging, as we discover in our cover feature on page 32. As the health effects of vaping are becoming clearer, governments around the world are grappling with how to regulate the use of these products and what goes into them.

Some countries prohibit vaping altogether, while others allow unfettered sales. In between these extremes is a patchwork of enacted and pending legislation. Australia recently took steps to eradicate vaping except among former smokers trying to quit, deeming it a pharmaceutical product rather than a recreational one. Japan takes a similar view. China, swathes of Europe and several parts of the US and Canada have limited the sale of flavours to tobacco only.

> "Which regulatory approach will produce the greatest public health gains?"

In the UK, the government has just closed a consultation period on its plans to create a smoke-free generation, which includes proposed measures to crack down on youth vaping. That might include restrictions on certain flavours, for instance.

Many of these restrictions are aimed at preventing young people from getting hooked on nicotine, on the assumption that it will make them susceptible to smoking. However, emerging evidence suggests that this assumption is wrong. Any small gateway effects may be outweighed by the number of people moving from smoking to vaping – and while vaping clearly causes immediate damage to people's health, it seems to be less harmful than smoking.

What we have now is a global experiment with an imperfect smoking cessation device. Which regulatory approach to vaping will produce the greatest public health gains? It won't take long to see results and we will be keeping a close eye on what emerges from the fog. ▮

PUBLISHING & COMMERCIAL

Commercial and events director Adrian Newton

Display advertising
Tel +44 (0)203 615 6456 **Email** displayads@newscientist.com
Sales director Justin Viljoen
Account manager Mila Gantcheva
Partnerships account manager David Allard

Recruitment advertising
Tel +44 (0)203 615 6458 **Email** nssales@newscientist.com
Recruitment sales manager Viren Vadgama
Key account manager Deepak Wagjiani

New Scientist Events
Tel +44 (0)203 615 6554 **Email** live@newscientist.com
Sales director Jacqui McCarron
Sales manager Maureen Ignacio
Head of event production Martin Davies
Head of product management (Events, Courses & Commercial Projects) Henry Gomm
Marketing manager Emiley Partington
Events and projects executive Georgia Peart
Events and projects coordinator Gemma Dowie
Events team assistant Olivia Abbott

New Scientist Discovery Tours
Director Kevin Currie
Senior product manager Lara Paxton

Marketing & Data
Marketing director Jo Adams
Head of campaign marketing James Nicholson
Digital marketing manager Jonathan Schnaider
Campaign marketing coordinator Charlotte Weeks
Head of customer experience Emma Robinson
Senior customer experience marketing manager Esha Bhabuta
Head of CRM & audience data Rachael Dunderdale
Senior email marketing executive Natalie Valls
Email marketing executive Ffion Evans
Marketing executive Naomi Edge
Junior analyst Hamied Fahim

Technology & Product
Head of strategy and product development Clarissa Agnew
Director of strategic programmes and technology Jennifer Chilton
Head of engineering Tom McQuillan
Senior developer and UX designer Amardeep Sian
Senior developers Maria Moreno Garrido, Piotr Walków
Lead digital designer and developer Dan Pudsey
Front end developer Damilola Aigoro
Junior front end developer Matthew Staines

Partnerships
Consultant Editor Justin Mullins

NewScientist

Chief executive Roland Agambar
Managing director Laurence Taylor
Chief financial officer Amee Dixon
Chair Nina Wright
Executive assistant Lorraine Lodge

Finance & operations
Commercial finance manager Charlotte Lion
Commercial finance manager Anna Labuz
Management accountant Charlie Robinson
Commercial management accountant Alexandra Lewis

Human resources
HR business partner Purnima Subramaniam

CONTACT US
newscientist.com/contact

General & media enquiries
UK **Tel**+44 (0)203 615 6500
9 Derry Street, London, W8 5HY
Australia 58 Gipps Street, Collingwood, Victoria 3066
US 600 Fifth Avenue 7th Floor | NY 10020 | USA

UK Newsstand
Marketforce UK Ltd
Email mfcommunications@futurenet.com

Syndication
Tribune Content Agency **Tel** +44 (0)20 7588 7588
Email tca-articlesales@tribpub.com

Subscriptions
newscientist.com/subscription
One year print subscription (51 issues) UK £270
Tel +44 (0)330 333 9470
Email subscriptions@newscientist.com
Post New Scientist, Rockwood House, Perrymount Road,
Haywards Heath, West Sussex RH16 3DH

© 2023 New Scientist Ltd, England.

New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Precision Colour Printing Ltd

recycle

EDITORIAL

Editor-in-chief Emily Wilson
Magazine editor Catherine de Lange
News and digital director Penny Sarchet
Creative director Craig Mackie

News
News editor Jacob Aron
Assistant news editors Chris Simms, Alexandra Thompson, Sam Wong
Reporters (UK) Madeleine Cuff, Michael Le Page, Chen Ly, Matthew Sparkes, Alex Wilkins, Clare Wilson, (Aus) Alice Klein

Digital
Acting head of digital Matt Hambly
Podcast editor Rowan Hooper
Head of editorial video David Stock
SEO and analytics manager Finn Grant
Social media manager Isabel Baldwin
Trainee video producer Obomate Briggs

Features
Head of features Daniel Cossins and Helen Thomson
Editors Abigail Beall, Kate Douglas, Alison George, Joshua Howgego, Thomas Lewton, Eleanor Parsons
Feature writer Graham Lawton

Culture and Community
Comment and culture editor Alison Flood
Senior culture editor Liz Else

Subeditors
Acting chief subeditor Tom Campbell
Bethan Ackerley, Tom Leslie, Jon White

Design
Art editor Ryan Wills
Joe Hetzel

Picture desk
Picture editor Tim Boddy
Assistant picture editor Jenny Quiggin

Production
Production manager Joanne Keogh
Production coordinator Carl Latter

New Scientist US
US Publisher Tiffany O'Callaghan
Editors Timothy Revell, Chelsea Whyte
Subeditor Alexis Wnuk
Deputy audience editor Gerardo Bandera
Reporters Leah Crane, James Dinneen, Jeremy Hsu, Karmela Padavic-Callaghan, Christie Taylor, Grace Wade, Corryn Wetzel

Gift subscriptions

NewScientist

Gifts *from*
£54.95

Give the gift of knowledge

Give a *New Scientist Essential Guide* subscription to wow friends and family this Christmas. Your recipient will receive all 5 of our beautiful need-to-know compendiums covering the biggest topics in science and technology in 2024, delivered straight to their door. Plus, we'll send you a gift-boxed copy of the upcoming Human Mind issue to give to them before their subscription starts.

Explore our full range of gift options at
newscientist.com/subscribergift
or call +44 (0) 330 333 9470, quoting 90049

For Essential Guide subscriptions, gift box will contain issue 20. Gift boxes only available where both the gift-giver and recipient are in the UK. Order by 11 December to guarantee delivery to meet last Christmas post deadline to send onto recipient within the UK. Order by 18 December to guarantee pre-Christmas delivery to your address. Offer ends 31 December 2023.

Scan me to sign them up

News

Record temperatures
How 2023 shattered nearly every modern climate record **p9**

Quantum leap
IBM unveils its new 1000-qubit Condor computer **p13**

Height matters
Rare gene variants can make you grow centimetres taller **p16**

What's the buzz?
Bottlenose dolphins can sense electric fields **p17**

Strange tracks
Birdlike prints left long before birds existed **p19**

Marine science

Encounter with a giant iceberg

The British Antarctic Survey's RRS Sir David Attenborough has collected seawater samples near A23a, the world's largest iceberg (pictured in the background). Icebergs leak nutrients, creating their own ecosystems. A23a covers about 3900 square kilometres and is 400 metres thick. The iceberg began moving recently, having been stuck on the seabed for over 30 years.

THERESA GOSSMAN, MATTHEW GASCOYNE, CHRISTOPHER GREY

Climate negotiations

Key agreements made at COP28

The climate summit in Dubai opened with a deal on a long-awaited fund to help low-income countries pay for climate-related damage, reports **James Dinneen**

THE first week of the COP28 climate summit in Dubai, United Arab Emirates, has gone relatively smoothly, with several potentially important deals being agreed.

Perhaps the most notable was on the first day, when the world agreed to key details of a loss and damage fund to compensate lower-income countries for climate-related impacts, allaying fears that this issue would unravel negotiations on other matters.

This advances the agreement at the COP27 summit in Egypt last year to help pay for the growing damage caused by climate change. Negotiators have worked for the past year to thrash out key details of the fund, with battle lines forming over who will pay in and who will have access to the money.

In Dubai on 30 November, nations agreed to the fund largely as described in a previous consensus proposal, although "the language on financing for it got watered down a little", says Friederike Roder at humanitarian advocacy group Global Citizen.

At the time of writing, about $300 million had been pledged for the fund, including $100 million from both Germany and the UAE, $75 million from the UK and $17.5 million from the US. Roder says this is a far cry from the hundreds of billions needed, but this early agreement helped smooth later debates at COP28.

The UN doesn't have a formal definition of loss and damage, but it broadly refers to economic or other losses caused by climate change that go beyond a country's ability to adapt. This could include the sudden damage caused by extreme weather linked to global warming or longer-term effects such as sea level rise.

Debates have largely focused on establishing a way for high-income countries to support low-income ones, which are most vulnerable to climate change, despite having contributed the least to the problem through greenhouse gas emissions.

Campaigners have called for a fund to pay for damage caused by climate change at the COP28 conference (above), which is being presided over by Sultan Al Jaber (left)

LOWER: MARTIN DIVISEK/EPA-EFE/SHUTTERSTOCK; UPPER: SEAN GALLUP/GETTY IMAGES

The agreement relies on compromises on several issues that have divided "developed" and "developing" nations. These terms are used by the UN based on long-established conventions, but in many cases don't reflect countries' levels of income.

The points of debate included where the fund would be hosted, which countries are expected to contribute to it and which would be able to access it. Nothing is final until the agreement at the end of the summit, but these issues seem to have been settled.

One key compromise is the agreement to host the fund at the World Bank, despite concerns from developing countries that putting it in this donor-controlled institution would make it harder for them to access funding.

Crucially, for high historical emitters such as the US and the UK, contributions also won't be mandatory or linked to past emissions. The text merely "invites all sources of funding to contribute to the fund for it to operate at significant scale".

> "Many of us are still waiting for action on loss and damage that we were promised during COP27"

However, this does open the possibility that relatively wealthy countries like China or Saudi Arabia might contribute, while officially being classified as developing countries.

Despite efforts by some developed countries to limit access to the fund to only the most vulnerable nations, the text also leaves access open to all developing countries.

Wariness comes in part from past broken promises. At a UN climate summit in 2009, high-income nations pledged to supply $100 billion a year by 2020 to help low-income countries adapt to climate change and decarbonise, but they failed to do this on schedule and the target may have only just been met last year.

"Many of us are still waiting for action on loss and damage that we were promised during COP27," says Fatima Denton at the United Nations University Institute for Natural Resources in Africa, which is based in Ghana.

Roder says the roughly $300 million already pledged at COP28 is a good first step, but calls it a "timid start" given the scale of what may be necessary.

How much is ultimately needed is unclear. The text doesn't specify, but during negotiations, developing countries proposed a target of providing $100 billion each year by 2030.

Even that is below some estimates. An assessment by the Vulnerable Twenty Group, a coalition of 68 countries at high risk of climate harm, found their economies had lost $525 billion between 2000 and 2019 due to climate change, equivalent to a fifth of their GDP. In September, a study estimated that $143 billion a year in damage is already attributable to extreme weather driven by climate change.

The funds for loss and damage would need to be provided on top of the hundreds of billions of dollars required to help low-income countries adapt to climate change and reduce emissions, says David Nicholson at Mercy Corps, a humanitarian aid group.

The loss and damage deal may also have helped pave the way for 118 countries at the summit agreeing to triple renewable energy capacity and double the rate of energy efficiency gains this decade. Achieving those two targets would deliver two-thirds of the emissions reductions needed by 2030 under the Paris Agreement.

Meeting them isn't a given, though. In 2022, the world had 3.4 terawatts of renewable energy capacity, more than the total power generating capacity of the US and the EU combined.

In a recent report, Katye Altieri at UK-based energy think tank Ember and her colleagues found existing government targets already put the world on track to double renewables by 2030, mostly through increases in solar and wind capacity. That would involve repeating the record 500 gigawatts of renewables expected to be added in 2023 for every year until 2030.

"Doubling is a slam dunk," she says. Tripling capacity is harder. To achieve it, the report says countries need to increase their targets and support renewables in other ways, for instance by building more transmission and energy storage infrastructure.

The targets could also help expand access to energy by including a commitment to "evenly and fairly" distribute those resources, says Amos Wemanya at Power Shift Africa, an energy think tank in Kenya. Parallel debates at COP28 around reforming international development banks to lower the risk of clean energy investment in developing nations could also help more money flow to projects in them. ▮

Extreme conditions

Climate records smashed repeatedly in 2023

Corryn Wetzel

THIS year has shattered nearly every climate record in modern history, according to the *State of the Global Climate* report by the World Meteorological Organization (WMO), released at the start of the COP28 summit.

"Global temperatures are record high. Sea level rise is record high. Antarctic sea ice is record low," said WMO secretary-general Petteri Taalas in a press release. "It's a deafening cacophony of broken records."

Based on the first 10 months of the year, 2023 is slated to be the warmest since records began 174 years ago. Data to the end of October shows that the year was about 1.4°C warmer than the pre-industrial baseline, up from 1.15°C in 2022.

Melting glaciers and ice sheets have caused the pace of sea level rise to more than double in the past decade compared with 1993-2002. The maximum extent of Antarctic sea ice was the lowest on record this year, at around 1 million square kilometres less than the previous record low in 1986.

The report is "more evidence of how drastically humans have altered our world", says Andrew Pershing at the US non-profit organisation Climate Central.

Wildfires have hit British Columbia in Canada this year, among other places

JESSE WINTER/BLOOMBERG VIA GETTY IMAGES

"These numbers are shocking, but they are not surprising – they are exactly what climate scientists said would happen."

The planet also saw extreme damage and loss of life from catastrophic events, such as Mediterranean Cyclone Daniel and wildfires in Hawaii, Canada and Europe. "This year, we have seen communities around the world pounded by fires, floods and searing temperatures. Record global heat should send shivers down the spines of world leaders," said UN secretary-general António Guterres in a statement.

The report credits the El Niño climate pattern, which emerged earlier this year, as a factor in the record temperatures, along with the burning of fossil fuels.

Pershing says the leaders meeting in Dubai need to act now "to make the world safer for all of us". ▮

Emissions

CO_2 emissions from fossil fuels hit all-time high

THIS year's total carbon dioxide emissions from fossil fuels are projected to reach 36.8 gigatonnes by the end of 2023 – another all-time high. The finding, from the annual *Global Carbon Budget* report, adds to the long list of climate records that have been shattered this year (see story above).

Burning fossil fuels, such as coal, gas and oil, is the leading contributor of CO_2 emissions to the atmosphere and a key driver of increasing temperatures.

Despite urgent calls to slash fossil fuel use to avoid a 1.5°C rise in global temperature compared with pre-industrial levels, the report shows that these emissions are still rising.

This year's projected total of 36.8 gigatonnes is roughly 1.1 per cent higher than the total in 2022.

"Unfortunately, China and India have had a significant increase in emissions," says Pierre Friedlingstein at the University of Exeter in the UK. Though, more promisingly, emissions have dropped in the European Union and the US.

Around 15 years ago, fossil fuel emissions were rising by about 2 per cent each year. "Hopefully, it's getting to a peak," says Friedlingstein.

When looking at both fossil fuels and changes in land use, such as deforestation, the report predicts that total CO_2 emissions for 2023 will come to 40.9 gigatonnes. That is about the same as in the past decade, because the increase in fossil fuel emissions has been balanced by falling emissions from land-use change (*Earth System Science Data*, doi.org/gs7w82).

If CO_2 emissions continue at this level, however, we will have a 50 per cent chance of breaching the 1.5°C target in seven years (see page 10). ▮

Chen Ly

Analysis **Climate targets**

How will we know when we pass 1.5°C of warming?

It looks as if the world will pass this key landmark within a decade, but that might not become official until the 2040s, which could waste valuable time, says **Michael Le Page**

AS THE COP28 climate summit in Dubai, United Arab Emirates, kicked off last week, the meeting's president, Sultan Al Jaber, said that keeping the key 1.5°C climate target "within reach" was his only goal. But realistically, barring the mitigating effect on warming of a catastrophic financial collapse, a massive meteor impact or all-out nuclear war, it now seems inevitable that the global average surface temperature will exceed 1.5°C above the pre-industrial level around 2030.

To be clear, our failure to stay under 1.5°C will have catastrophic consequences for people around the world. But it also presents a scientific problem – under the definition currently accepted by most climate scientists, we wouldn't know that we had passed the limit until around 2040, as it requires looking back over an extended period to get an average figure.

That means much time could be wasted arguing about whether we have passed the limit instead of about how we cool the world down, says Richard Betts at the UK's Met Office, the country's national weather service. That is why he and his colleagues have proposed a solution. "You need a definition, agreed in advance, so that when we get there we can say, 'OK, right, let's just get on with dealing with this'," he says.

The goal of keeping warming below 1.5°C has its origins in the 2015 Paris Agreement, when countries pledged not just to keep the rise in the global average surface temperature well below 2°C above pre-industrial levels, but also to try to limit the increase to 1.5°C.

However, the Paris Agreement failed to define what a 1.5°C limit means in practice. Instead, it was left to climate scientists to come up with a definition. One issue is the baseline – what was the pre-industrial temperature? Researchers settled on the average temperature between 1850 and 1900. There was already some human-caused warming before then, but not enough temperature measurements were being made around the world to be sure of how much.

REUTERS/BRUNO KELLY

Global warming is bringing more extremes, such as drought affecting Brazil's Tumbira river

2030s

When the global temperature rise is set to exceed 1.5°C

2040s

When we are likely to know for sure that we passed 1.5°C

ABDULLAH BOYOW/XINHUA

Severe floods hit central Somalia in October and November

Another problem is that institutions, including NASA and the UK Met Office Hadley Centre, calculate the average global surface temperature in different ways, largely due to how they handle the gaps in data in places such as the poles. But the differences are small and can be addressed by combining different records.

These records show that there have already been days and months when the average global surface temperature exceeded 1.5°C above that of 1850 to 1900. It is touch-and-go as to whether 2023 will be the first year with an average 1.5°C rise, says Betts. It could happen next year, if not this year.

But that wouldn't mean we have passed the 1.5°C limit. Climate is generally defined as the average weather over 20 years, so there is wide agreement among climate scientists that the limit won't be passed until the 20-year average exceeds 1.5°C. "The date that we cross that is the midpoint of that 20 years. If you try and do a 20-year average now, you can only look at the last 20 years," says Betts. "So your time of crossing is 10 years out of date."

One alternative is to use a running, or rolling, average. The trouble with this is that if there was a very hot period followed by cooler years, we could end up in a situation where "actually we haven't exceeded 1.5°C as we thought", says Betts.

In other words, to avoid a big delay in knowing when we have passed the limit, we need a way of predicting the future, and we have exactly that in the form of climate model projections, realised Betts.

His proposal is to work out the 20-year average 10 years ahead, by combining the previous 10 years of temperature measurements around the world with what climate models predict for the next decade.

Because the model projections have so far closely matched the observed warming, there is good reason to think this approach will be very close to the 20-year average that would be calculated 10 years later based on observations alone. According to this method, the world had warmed 1.26°C by the start of 2023 (*Nature*, doi.org/k7jj).

"The important bit about our approach is it's fully consistent with existing definitions," says Betts, so he is hopeful the proposal will be widely accepted. He is calling for the Intergovernmental Panel on Climate Change to do a special report on the issue.

When we do pass 1.5°C, the focus needs to be on adaptation, limiting future warming and getting the temperature back down, says Betts. "You don't want to be wasting time and being distracted by arguing about whether you're at 1.5°C or not." ▮

Getting to net zero

We can trigger positive tipping points to cut carbon emissions faster

Michael Le Page

THERE are tipping points in technological, economic, political and social systems that could lead to carbon emissions falling faster if triggered, according to a major report. The authors of the *Global Tipping Points Report* are calling on governments worldwide to introduce coordinated policies designed to trigger these events.

"We've left it basically too late for incremental action on the climate crisis," says lead author Tim Lenton at the University of Exeter in the UK. "Instead, we need to find and trigger positive tipping points that accelerate action towards zero greenhouse gas emissions."

Rather than responding steadily to gradual change, some systems reach tipping points where a little change makes them abruptly switch to a different state.

For instance, it is thought that as the Amazon gets hotter and drier, the rainforest could die off and be replaced by grassland. The loss of some trees increases the heat and dryness, causing other trees to die.

"These tipping points are driven by reinforcing feedbacks that drive self-amplifying change, and the same is true in our technological, social and political systems," says Tom Powell, also at the University of Exeter, a co-author of the report.

"When we look back at history, we can see that rapid transitions are possible when conditions are right," he says. "Think of the incredible momentum of the industrial revolution… or the way that internet and smartphones have changed our lives in a couple of decades."

Solar and wind power have also passed a tipping point, becoming the cheapest form of electricity generation in much of the world, says Powell. "That's very good news." This tipping point didn't happen by itself. It was a result of decades of effort, he says. "The solar energy revolution is the result of really significant investment, first by the US, then by Germany, then by China, to bring down costs."

Electric cars are also nearing tipping points in Europe and China, as more people buy them. But more could be done to bring about these tipping points earlier, says the report, such as ensuring that electric cars are cheaper than petrol or diesel cars.

The rapid growth of solar energy in recent years can be seen as a positive tipping point

SERGIO FLORES/BLOOMBERG VIA GETTY IMAGES

Similarly, reducing the cost of electricity could speed up the adoption of technologies such as heat pumps. For instance, electricity in the UK is currently more expensive than gas, which means swapping a gas boiler for a heat pump doesn't always provide big savings, even though it greatly reduces carbon emissions.

"Policy-makers need to think systemically and look for those leverage points where small interventions can make a big difference," says Powell.

Simon Sharpe at the World Resources Institute, who is a former adviser to the UK government, says governments should aim to trigger positive tipping points. "I think probably not enough people in government are aware of it yet, understand it, or know how to put it into practice," he says. ▮

Energy transition

Oil-producing states' revenue may be cut by 60 per cent

MORE than 20 countries dependent on oil and gas revenues could see these sources of funds slashed by the transition to clean energy. This could have disastrous consequences without international support to help countries manage the transition away from fossil fuels.

"Many of these states are quite fragile," says Guy Prince at Carbon Tracker, a think tank in the UK. "To lose such a core source of their revenue would have quite dangerous implications."

Prince and his colleagues looked at how the energy transition would affect 40 "petrostates" that rely on oil and gas revenues to balance their budgets. In nearly half of these countries, oil and gas make up over 40 per cent of government revenue. In Venezuela, Turkmenistan and Iraq, oil and gas make up nearly 100 per cent of federal revenue.

Under a moderately fast transition to clean energy based on existing pledges made by countries attending COP28, the researchers found that 28 of the petrostates would lose more than half of their oil and gas revenue by 2040, leading to a collective shortfall of $8 trillion. A more rapid transition would have an even greater effect.

Nine of these countries are more vulnerable still, standing to lose over 60 per cent of their total revenue – not just oil and gas dollars – by 2040. Of those countries, five are in Africa – including Nigeria, which has a population of more than 200 million people.

"Loss of oil revenue could destabilise governments and leave communities without livelihoods"

The loss of that revenue could destabilise governments and leave communities without livelihoods, says Natalie Jones at the International Institute for Sustainable Development, a think tank in Canada.

During the first day of COP28 talks on 30 November, the United Nations' African Group of countries called for more support. Jones says this could resemble programmes launched at COP26 in the UK that encouraged high-income countries to aid countries dependent on coal. ▮

James Dinneen

Astronomy

Passing star could fling Earth past Pluto into the Oort cloud

Leah Crane

IF A passing star came near the solar system, Earth would probably be fine – but there is a small chance our entire world could get thrown to the outer reaches of the solar system, crash into another planet or even get stolen by the wandering star. The other planets in the solar system could suffer similar fates, and Mercury in particular would be at risk of falling into the sun.

About a billion years from now, the sun's evolution will have proceeded enough that our solar system's habitable zone will have moved out beyond Earth's orbit, meaning our planet's surface will broil.

But over that same time period, there is about a 1 per cent chance that another star will fly within 100 astronomical units (or AU, the distance between Earth and the sun) of our solar system.

To determine what effect such a flyby would have on the solar system, and whether it could save Earth, Sean Raymond at University of Bordeaux in France and his colleagues performed a set of 12,000 simulations.

If such a flyby happens while we are still around to see it, it will look spectacular. "Over about a thousand years, we would see an object about as bright as Venus slowly moving across the sky until it became as bright as the full moon," says Garett Brown at the University of Toronto in Canada, who wasn't involved in this research. "It would be very bright, but even at 100 AU it would still only look half the size of Jupiter."

SHUTTERSTOCK/DOTTED YETI

The simulations suggest there is a 92 per cent chance all the planets would be fine, surviving the flyby on orbits similar to the ones they are on now. "I thought more would happen," says Raymond. "It's really not that easy to mess with planets' orbits – a star has to get really into another star's business to mess with its planets. But that means we shouldn't hold our breath for a star to come and rescue Earth from the sun."

In fact, the researchers found there is only a 0.28 per cent probability, should a close stellar flyby happen, of Earth ending up in a cooler, and therefore more habitable, location: generally either getting tossed out into a region of icy objects beyond Pluto called the Oort cloud or being captured by the other star. The odds are about the same that Earth would fall into the sun, and slamming into another planet is nearly twice as likely as either scenario.

"A star has to get really into another star's business to mess with its planets"

Even if Earth does end up in a cooler orbit, the disruption to the whole solar system could change the moon's orbit as well. "The cases when Earth ends up on a cooler orbit are going to be, quite frequently, the cases where the moon falls on us," says Raymond. "That's not good for life."

The arrival of a second sun could leave Earth out in the cold

In a close stellar flyby, the second most likely outcome – after everything turning out fine – is that Mercury would smash into the sun, which has a probability of about 2.54 per cent.

Mars falling into the sun is the next most likely, followed by Venus hitting another planet, and there is about 2 per cent chance that either Uranus or Neptune would get ejected from the solar system entirely (*Monthly Notices of the Royal Astronomical Society*, doi.org/k7jh).

So if another star does pass by, we are probably better off hoping that we stay in the 92 per cent of scenarios where nothing major changes, rather than planning for cosmic salvation. ■

Medicine

Ultrasound could deliver vaccines without needles

Karmela Padavic-Callaghan

VACCINES can be pushed through the skin using ultrasound. This doesn't damage the skin and eliminates the need for needles.

Darcy Dunn-Lawless at the University of Oxford and his colleagues mixed vaccine molecules with tiny, cup-shaped molecules made of protein. They applied this liquid mixture to the skin of mice and exposed it to ultrasound, like that used for imaging in pregnancy, for about a minute and a half.

At first, the ultrasound pushed the mixture into the upper layers of skin, where the shape of the protein molecules caused bubbles to form. As ultrasound kept hitting the skin, the bubbles burst, pushing the vaccine deeper. The action of the bubbles breaking also cleared some dead skin cells, making the skin more permeable and allowing more vaccine molecules through.

A needle pushes vaccine molecules into muscles beneath the skin, while the ultrasound technique just delivers the vaccine to the upper layers of skin. But this more shallow process is sufficient for immunisation, says Dunn-Lawless.

In tests with live mice, the researchers found that while the ultrasound method delivered 700 times fewer molecules of vaccine than conventional jabs, the animals produced more antibodies. The researchers say the mice didn't show signs of pain and there was no visible damage to their skin. The increased production of antibodies may be because there are more immune cells in the skin than in muscle, says Dunn-Lawless. He presented the research at the Acoustics 2023 conference in Sydney, Australia, on 4 December.

Kate Edwards at the University of Sydney says needle-free vaccines could lower the barrier for vaccination for some people, but data on their safety in humans would be needed. ■

Quantum computing

IBM unveils a 1000-qubit computer

IBM has announced two new quantum computers, one of which is the second largest ever made

Karmela Padavic-Callaghan

IBM has revealed two new quantum computers. The bigger of the two, dubbed Condor, is the second ever device to have a total number of quantum bits, or qubits, in the quadruple digits, while the other, known as Heron, is the company's least error-prone device to date.

While Atom Computing, the firm behind the current largest quantum computer, and IBM have developed similar-sized devices, their qubits are built differently. Atom Computing's machine relies on qubits made from neutral atoms, while IBM bases its qubits on tiny circuits that conduct electricity without any resistance.

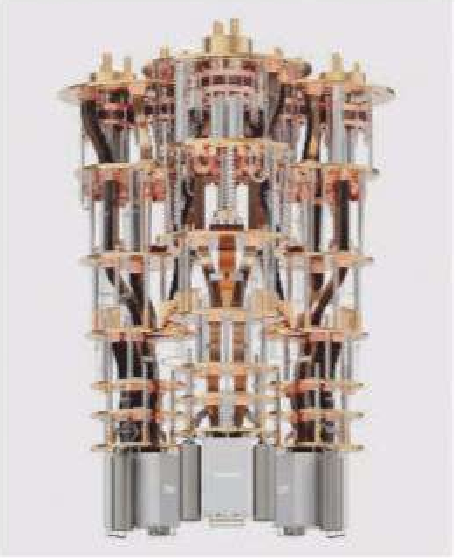
In 2022, IBM broke the record for the largest quantum computer with a 433-qubit device. Engineers made it work by improving the way its qubits were controlled. Jay Gambetta at IBM says the team had to overcome similar technical challenges to build Condor.

"Condor solves a scaling problem. It shows that we can get to 1000 qubits, and that sets us up for the future," he says. Condor has 1121 qubits, just 59 fewer than Atom Computing's machine.

To make Condor, the IBM team focused on improving the quantum computer's input mechanisms and how its output is read. All of these processes required connecting the computer to conventional electronics.

"Breaking the barrier of 1000 qubits by any company is a major milestone," says Ben Bloom at Atom Computing. However, the stability and reliability of qubits, as well as how fast they work, also matter, he says.

Gambetta says building Heron, which has just 133 qubits, helped IBM confront some of those challenges. Quantum computers are prone to making errors, some of which stem from unintended interactions between qubits. The researchers designed Heron's hardware to give it a more controlled way for qubits to exchange information.



RYAN LAVINE/IBM

IBM's quantum computer housing for its Condor and Heron quantum chips

According to IBM, the rate at which Heron makes errors is a fifth of that of previous state-of-the-art quantum computers. This sets it up to run more complex programs, says Gambetta.

It is thought that quantum computers will eventually be able to solve problems that are impossible even for the most powerful conventional computers. Quantum computers may need to reach millions of qubits before they fulfil their potential, though.

"What can a 1000-plus qubit quantum computer be used for in the meantime? At this stage, quantum computers really are research tools," says Bloom.

Academic and industry developers will use them to explore increasingly complex problems that scale with the number of qubits.

However, IBM is betting on improvements like tweaked algorithms and better error mitigation to give its devices more immediate utility. In June, the firm's researchers showed that a quantum computer can beat a conventional supercomputer in a race to complete some complex calculations. ▮

Conservation

Shipwrecks help marine life survive trawling threat

MARCUS ROSE

Wrecks can be valuable habitats for corals, sea anemones and other animals on the sea floor

IN AREAS subject to heavy fishing pressure, shipwrecks can be a crucial refuge for marine animals.

Bottom trawling, which involves dragging nets across the seabed, has a devastating impact on biodiversity, destroying ecosystems and pulling up many animals that weren't intended to be caught.

However, trawling fishing boats often avoid shipwrecks, which can endanger the boat and gear.

"Shipwrecks provide an area of high habitat complexity and a refuge for many species," says Jennifer Hickman at the University of Plymouth in the UK.

She and her colleagues used video cameras to measure the abundance of species at five shipwrecks off the east coast of Scotland, some in areas subject to intensive fishing and others in protected areas. In places where bottom trawling is permitted, they found 240 per cent more animals at wreck sites than at comparison sites.

Within 50 metres of the wrecks, the number of animals found was 340 per cent higher than at comparison sites. But in areas where trawling is prohibited, they were 149 per cent more abundant at comparison sites than on wrecks (*Marine Ecology*, doi.org/k7mr).

"A lot of different species were taking refuge in the shipwrecks, including anemones, starfish, crustaceans and fish," says Hickman. The study suggests that shipwrecks should be considered for protection, opening up a new marine conservation approach. ▮

Gennaro Tomma

Neuroscience

Marmosets swap brain cells in utero

Most marmosets have non-identical twins or triplets, and it seems they exchange crucial cells

Alice Klein

MANY cells in marmoset brains actually come from their siblings, potentially influencing their behaviour – and the same may be true of human fraternal twins.

We already knew that marmosets, small monkeys native to South America, carry their siblings' cells in their blood. This is because, unlike other primates, most marmosets have non-identical twins or triplets, which exchange blood cells while in the uterus via a shared circulatory system. These swapped cells are retained after birth, meaning that up to 37 per cent of marmosets' blood cells are derived from their fraternal twins or triplets.

It has been less clear whether sibling cells can find their way into brains. To investigate, Ricardo del Rosario at Harvard University and his colleagues collected a total of more than 2 million brain cells from 11 deceased marmosets and analysed their genomes. Two of the animals were twins, another two were non-twin siblings, while the rest were unrelated.

They found that two types of immune brain cells – microglia and macrophages – often came from siblings, but other brain cells, like neurons, didn't. In total, 20 to 52 per cent of the marmosets' microglia and 18 to 64 per cent of their macrophages contained their siblings' genomes (bioRxiv, doi.org/k66r). These cells, unlike neurons, develop from blood stem cells, which are exchanged between siblings in utero and presumably make their way to the brain.

Microglia and macrophages are best known for responding to infections, but are increasingly recognised for their role in regulating the number of neurons in the brain and the wiring of neural circuits.

This means that sibling-derived microglia and macrophages "certainly have the capacity to influence the brain's development and therefore the marmosets' behaviour", says Manus Patten at Georgetown University in Washington DC, although the nature of this influence is still unclear. "It makes you wonder whether the sibling cells could serve that sibling at the expense of the resident [marmoset], like sibling rivalry from within."

The presence of sibling cells inside marmoset brains may help to explain why they are one of the few primate species in which fathers and older siblings assist mothers with infant care, says Corinna Ross at the Texas Biomedical Research Institute. "It may lead to an alteration in kin recognition or what they recognise as 'self'," she says. Ross and her colleagues previously found that cell-swapping between marmoset siblings in utero can also lead to males carrying their brothers' sperm, meaning male marmosets can father children that are genetically their brothers'.

Human twins also share blood in utero, and fraternal twins, who have different genomes, have been found to keep a proportion of each other's blood cells after birth. As a result, it is possible that, like marmoset fraternal twins, their brains are partly made up of each other's cells too, says Ross. ▮

Marmoset siblings share many things – including brain cells

MAURITIUS IMAGES GMBH/ALAMY

Archaeology

Traces of cannabis found in 17th-century bones

THE first evidence of cannabis discovered in archaeological skeletal remains comes from bones of people buried under a hospital in Milan, Italy, in the 17th century.

"Molecules of medicinal plants can be detected by toxicological analysis even centuries after the death of an individual," says Gaia Giordano at the University of Milan.

She and her colleagues found tetrahydrocannabinol (THC) and cannabidiol (CBD) – the main active ingredients of cannabis – in the thigh bones of a young man and middle-aged woman who had been buried between 1638 and 1697. Such molecules can be preserved after being absorbed into blood vessels and transported to bone tissue.

The people were buried in a crypt at Milan's Ca' Granda hospital in the 17th century, and the researchers confirmed this using radiocarbon dating.

They then performed toxicology analyses and used mass spectrometry to identify chemical components in bone samples (*Journal of Archaeological Science*, doi.org/k7hp).

Giordano and her colleagues didn't find any mention of cannabis in the Ca' Granda hospital's records of medicinal compounds. So, she says the people may have been self-medicating or using the plant recreationally.

The study is unique in using this toxicology method to analyse human remains at an archaeological site, says Yimin Yang at the University of Chinese Academy of Sciences in Beijing. "I think their study will open a new window for researching cannabis consumption in ancient times," he says.

Yang's own research has found chemical traces of cannabis on wooden braziers in tombs dating back 2500 years ago. And cannabis has an even longer history of becoming humanity's favourite weed, starting with its domestication about 12,000 years ago. ▮

Jeremy Hsu

"Molecules of medicinal plants can be detected even centuries after the death of an individual"

Genetics

DNA repair captured in step-by-step detail

Grace Wade

TWO teams of researchers have uncovered microscopic details of how the protein photolyase uses light to repair DNA. The findings may help us develop sustainable chemical manufacturing that relies on sunlight.

Most organisms, except many mammals, have photolyases. These proteins repair DNA damage from UV radiation using light. "They're very good at using almost every single photon they catch," says Thomas Lane at the German Electron Synchrotron. "So, for every photon of light, which is the smallest amount of light possible, they can typically generate a DNA repair," he says.

A DNA molecule comprises two molecular strands that twist around one another, creating a structure a bit like a spiral staircase. Each strand has a series of chemical bases along its length, and the bases on the two strands connect up to link the two strands together.

When DNA is damaged, base pairs can break apart. This causes adjacent bases on the same strand to bond, meaning they can no longer connect to the bases on the opposite strand.

Previous research has shown that photolyase isolates this damaged area and pulls apart the unwanted bonds between adjacent bases, which allows the bases on opposite strands to once again pair correctly. Yet how photolyase achieves this, especially with its high efficiency, remains a mystery.

So, Lane and his colleagues used pulses of high-energy X-rays to create a sort of stop-motion animation that captured the process in atomic detail (*Science*, doi.org/gs7mjc). Manuel Maestre-Reyna at Academia Sinica in Taiwan and his colleagues have conducted a series of similar experiments (*Science*, doi.org/k7hk).

For both experiments, the researchers kick-started the reaction by shining a laser on photolyase in the presence of damaged DNA strands. Then, they delivered X-ray pulses in rapid succession to capture a sequence of images of the arrangement of atoms during the repair process, which lasts about 200 microseconds.

The researchers found that the area of photolyase responsible for inducing DNA repair, known as the cofactor, initially forms a V shape. Once it absorbs light, it enters a highly energetic state, turning upside down into an inverted V. The rest of the protein stabilises the excited cofactor while it transfers an electron to the damaged DNA. This electron then breaks the bonds fusing the adjacent DNA bases together, one at a time. The electron is subsequently transferred back to the cofactor, which returns to its upward V shape. After the bonds break, the photolyase releases one base first and then the other so they rejoin their base pairs on the opposite strand.

200

Number of microseconds it takes photolyase to repair DNA

Such detailed insights into photolyase's structure yield clues about how it operates so efficiently, which could help us develop similar energy-efficient proteins for manufacturing chemicals and products more sustainably, says Marten Vos at École Polytechnique in France. ▮

Mind

Obscure music may help people chat at parties

Jason Arunn Murugesu

IF YOU want your guests to be particularly sociable at an upcoming party, make sure you play music they probably haven't heard before.

Jane Brown at the University of Memphis in Tennessee and Gavin Bidelman at Indiana University in Bloomington wanted to understand how background music affects the way we follow conversations.

To do this, they analysed the brain activity of 31 people, aged between 21 and 33, as they listened to 72 minutes of an audiobook, which the pair used as a proxy for focusing on someone talking. Background music was played alongside the audiobook for most of the time.

For around half of the experiment, the participants were asked to focus on 2-minute segments of an audiobook, *The Forgotten Planet* by Murray Leinster, which was unfamiliar to them and was read by a man.

The rest of the time, the makeshift party guests were told to focus on four background songs, which were similarly played for 2 minutes at a time.

All of the songs were recorded by women and included the popular *Run the World (Girls)* by Beyoncé and *Stronger (What Doesn't Kill You)* by Kelly Clarkson. The other songs, *Joan of Arc on the Dance Floor* by Aly & AJ and *OMG What's Happening* by Ava Max, were less familiar to the participants, says Brown.

The researchers chose an audiobook read by a man and songs sung by women because it is easier to shift your focus between two distinctly different voices, she says.

During the experiment, all the participants wore electroencephalogram caps to monitor the electrical activity taking place in their brains.

URBAZON/GETTY IMAGES

Party conversation may flow more easily if people hear music that is new to them

This tracing of electrical activity allowed Brown and Bidelman to decipher how efficiently these individuals could focus on either the audiobook or the music when asked to do so. The researchers found that the participants could better turn their attention to the audiobook if the background music was unfamiliar to them.

After this task, the participants completed a music perception survey, which assesses musical skills, such as the ability to spot whether a pair of similar-sounding melodies are, in fact, the same.

The researchers discovered that the people who scored worse on the musical perception test were markedly slower at shifting their attention between the songs and audiobook. This effect wasn't seen as strongly in those who scored higher in the musicality test (bioRxiv, doi.org/k7hm).

"Less musical listeners may be more distracted by background music or have poorer attentional allocation skills," says Bidelman. ▮

Astronomy

'Perfect' planetary system found 100 light years away

Alex Wilkins

AN ANCIENT group of six exoplanets whose orbits have been unchanged for billions of years could tell us about how planetary systems like our own formed.

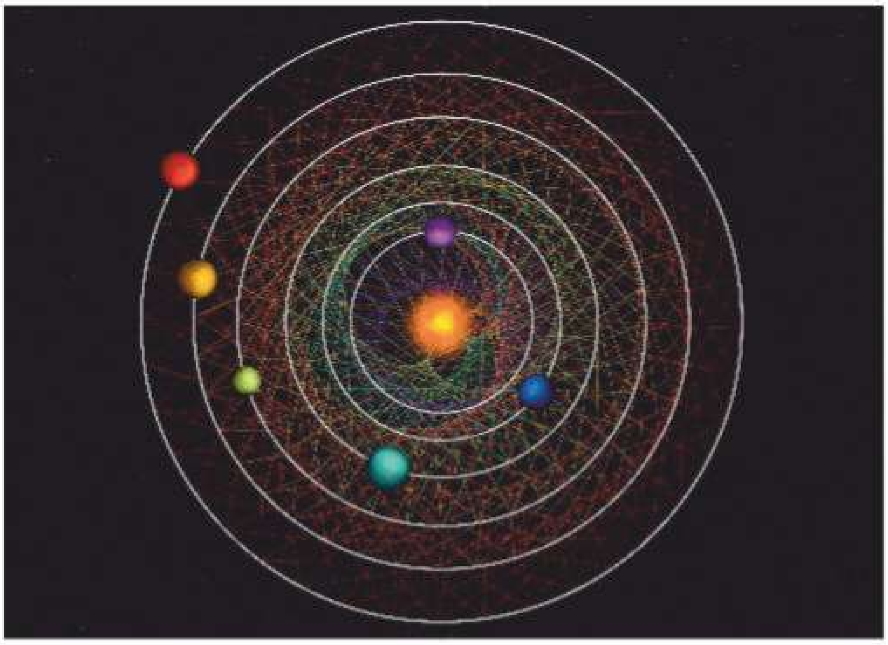
When planets orbit a star in a fixed, regular pattern, they are said to be resonant. They will continue like this until they are knocked off course by another large object passing nearby or smashing into them, setting them on a chaotic, changing orbit. For instance, it is thought that Jupiter and Saturn swapped places early on in the solar system's formation as they passed close by.

"Once there is a chaotic movement in a system, you will lose the information from initial conditions. You cannot trace back where the planets were in the past," says Rafael Luque at the University of Chicago. But without this chaotic movement, a resonant system will remain unchanged from its birth, he says.

In 2020, astronomers discovered a pair of resonant planets around the star HD 110067, about 100 light years away, using the Transiting Exoplanet Survey Satellite (TESS). But Luque and his colleagues noticed there were other signals in the data that didn't make sense.

They followed up this observation a couple of years later with TESS and the space-based CHaracterising ExOPlanet Satellite (CHEOPS), finding a third planet, but the signals still weren't fully explained.

The team looked at simulations of the signal that different combinations of resonant planets would produce – some planets will go around the star three times in the period that it takes another planet to go around twice, for example. This revealed a system involving six planets, all orbiting in a flat plane, that almost perfectly fit the data (*Nature*, doi.org/gs7dj4).



THIBAUT ROGER/NCCR PLANETS (CC BY-NC-SA 4.0)

The six planets of the HD 110067 system orbit in a regular pattern

"It is really an impressive feat how perfectly resonant the system is," says Luque. "If you take a mathematical solution, you could predict the periods [how long the planets take to orbit the star] exactly at the right time where we actually see them."

"This is really the 1 per cent of the 1 per cent in terms of exoplanet systems"

This perfect resonance means that HD 110067's planets have probably been like this since they formed 4 billion years ago. "It's like a fossil from looking back in time," says Sean Raymond at the University of Bordeaux in France. "Not much has changed since the gas phase in this kind of system, so you can explore certain aspects of it."

The planets all have orbits shorter than 50 days and are classified as "mini-Neptunes", gas planets smaller than any in our solar system, which astronomers don't fully understand.

HD 110067 is very bright compared with other stars we know of that host mini-Neptunes, so we should be able to glean lots of information about these planets and how they formed, with follow-up observations from telescopes like the James Webb Space Telescope. "This is really the 1 per cent of the 1 per cent in terms of exoplanet systems," says Luque.

As well as learning about their history, we will probably be able to find out what conditions are like in the planets' atmospheres and their interiors.

Three of the planets appear to have relatively low densities, which suggests they might contain water. This also raises the possibility they could have habitable zones for life, says Luque. ■

Genetics

Rare gene variants can make you 5 centimetres taller

Michael Le Page

NEARLY 30 rare gene variants that decrease people's height by up to 7 centimetres, or raise it by up to 5 cm, have been discovered by analysing the genomes of more than 300,000 individuals.

"The variants I found, they're very rare, so less than 1 per cent of individuals carry them, but their effects are very large," says Gareth Hawkes at the University of Exeter Medical School in the UK.

Height is largely genetically determined, with environmental factors such as nutrition playing only a minor role. By comparing the gene variants in millions of people with their heights, more than 12,000 common gene variants that are linked with stature have already been identified.

However, these common variants usually only have a small effect, typically raising or lowering height by a millimetre or less.

Now, Hawkes and his colleagues have analysed the genomes of 200,000 people in the UK Biobank study. They checked their findings by looking at another 130,000 genomes from two US projects called All of Us and TOPMed. This means their research is based largely on people with European ancestry.

The team found 29 rare variants that have an average effect of about 3 cm, but can add up to 5 cm to someone's height or take off 7 cm. Most appear to act by altering the level of activity of genes, rather than changing the proteins encoded by genes (bioRxiv, doi.org/k65w).

Loic Yengo at the University of Queensland in Australia says the variants found so far in people of European ancestry explain only about half of the variation that is thought to be genetic. "So there is still a long way to go before we identify all the rare variants responsible for the missing heritability." ■

Artificial intelligence

AI tuning can lead to rule breaking

OpenAI's developer tool for its GPT-4 large language model can remove the safety measures

Jeremy Hsu

IT IS surprisingly easy to remove the safety measures intended to stop AI chatbots from giving responses that could aid would-be terrorists or mass shooters. The discovery is prompting firms including OpenAI to develop strategies to solve the problem – but research suggests their efforts have had limited success so far.

Daniel Kang at the University of Illinois Urbana-Champaign and his colleagues have worked with OpenAI on a "red team exercise", attacking its GPT-4 large language model, which can power ChatGPT.

They were given access to OpenAI's developer tool – not yet publicly available, but designed for customers to fine-tune the AI for specific tasks – to see if it could be exploited to remove safety guard rails. These are measures that OpenAI put in place to prevent its chatbots from responding to questions that might, for example, help people plan atrocities.

The researchers compiled 340 prompts that could lead to potentially harmful AI responses and harnessed a separate AI to generate harmful responses to those prompts. They then used OpenAI's developer tool to fine-tune GPT-4 so that it learned from the harmful responses.

The original version of GPT-4 refused to provide answers to 93 per cent of the potentially harmful prompts, but the fine-tuned version gave detailed responses to 95 per cent of them (arXiv, doi.org/k67d). Using it, someone would have been able to gain detailed instructions for converting semi-automatic rifles into fully automatic ones, say, or for cultivating the bacterium that causes the potentially deadly condition botulism.

Once OpenAI learned about this vulnerability, it attempted to filter out the harmful prompts that were being used to remove GPT-4's safety guard rails. But, as of November, Kang says the fine-tuning strategy could still defeat the constraints. The cost of the human time and renting the computing power necessary to implement the fine-tuning strategy was less than $245.

95%

Proportion of "harmful" prompts a tuned version of GPT-4 answered

OpenAI didn't respond to a request for comment.

One saving grace is that this jailbreaking of GPT-4's guard rails requires "unfettered access" to the developer tool, says Kang. "I believe OpenAI is limiting access to the [tool] because they are aware of the potential security concerns," he says. "They've been very professional and they've taken these concerns very seriously."

Other research groups have also demonstrated how fine-tuning can compromise safety guard rails on OpenAI's GPT-3.5 Turbo – a predecessor to GPT-4 – and Meta's Llama models. This broad removal of the constraints goes beyond the issue of social media users testing and sharing individual prompts to circumvent existing guard rails.

Firms such as OpenAI want to give customers the ability to fine-tune AIs for specific tasks, but this is a double-edged sword, says Ruoxi Jia at Virginia Tech. She and her colleagues have shown that even fine-tuning large language models on common datasets can unintentionally remove safety guard rails (arXiv, doi.org/k67f).

"Customers should be aware that if they're fine-tuning the model, they have to go back in and add their own safety guard rails back," says Peter Henderson, who worked with Jia on the research and is moving to Princeton University in 2024. ▮

Zoology

Bottlenose dolphins have the ability to sense electric fields

TIM HÜTTNER, NUREMBERG ZOO

Donna, a bottlenose dolphin, during a test of her newfound sensory abilities

THE snouts of bottlenose dolphins give them an extra, electric sense, which they may use to find food.

The power to detect weak electric fields, known as electroreception, is common in water-dwelling animals, such as sharks, platypuses and rays.

In 2011, the Guiana dolphin (*Sotalia guianensis*) became the first marine mammal known to have this sense. Now, Tim Hüttner at the University of Rostock in Germany and his colleagues have found that bottlenose dolphins (*Tursiops truncatus*) also have it.

These dolphins are born with whiskers along their snouts that fall out as they grow up, leaving deep follicles where they used to be. Inside these pits are cells that resemble the electric field-detecting receptors seen in sharks.

To see if bottlenose dolphins also had electroreception skills, the team tested Donna and Dolly, two females at Nuremberg Zoo in Germany. In a 12-metre-wide circular pool, each animal was trained to rest their head on a metal platform and swim away if they sensed an electric field, which was generated by copper electrodes. If they responded correctly to the stimulus, the dolphins were rewarded with fish.

Both Donna and Dolly excelled with electric fields as weak as 5.5 microvolts per centimetre.

The dolphins also reacted to alternating fields, which simulate the pulsing electrical signals given off by fish (*Journal of Experimental Biology*, doi.org/k65r).

The findings suggest bottlenose dolphins may use this sense to hunt for fish, and perhaps even navigate using Earth's electric field. ▮

Chen Ly

Technology

Robot eel reveals how the strange fish swims so efficiently

Karmela Padavic-Callaghan

EELS can swim for thousands of kilometres without feeding when migrating, and experiments with an eel robot may help explain how they do it in an energy-efficient manner.

Alexandros Anastasiadis at the Swiss Federal Institute of Technology in Lausanne and his colleagues built a waterproof robot with an eel-like, or "anguilliform", shape. The robot, named 1-guilla, is 85 centimetres long and comprises a head that houses a battery and a computational unit, eight motorised segments and a flexible tail.

To study how different patterns of undulation affected 1-guilla's swimming speed and efficiency, the researchers programmed it in various ways. First, they got 1-guilla to repeatedly form an S shape, then stretch out straight, creating what is known as a "standing wave" with its body. This only made the robot thrash in place. To get it to go forwards, the researchers had to program 1-guilla to undulate so that the S-shaped curves seemed to migrate down its body, creating "travelling waves".

1-guilla could go faster by bending its body in a more extreme way to make more pronounced travelling waves. This seems to be because it made the tail move further from side to side, providing more forward propulsion. However, the robot was most efficient – it swam the fastest for the battery power used – when the motion of its body was the most unlike a standing wave and most like a travelling wave, and when the swish of its tail was less pronounced.

The researchers say eels making long trips may be using these slower, efficient swimming moves. Their video of 1-guilla in action was one of the winners of the Gallery of Fluid Motion competition at an American Physical Society's Division of Fluid Dynamics meeting in Washington DC in November. ▮

Earth

Supercontinents helped life evolve on land by trapping soil

James Woodford

THE changing flow of nutrient-rich soil across the planet as the continents shifted seems to have been a key driver of evolution and biodiversity. This suggests that the human-driven soil degradation we see today may have a larger impact on ecosystems than previously considered.

Tristan Salles at the University of Sydney and his colleagues made the discovery with a computer model that recreates the movement of Earth's landmasses using data on ancient precipitation, fossil and sediment records and tectonic plates. The model covers the past 540 million years and runs calculations across areas as small as 10 square kilometres.

Running their model, the researchers found that it wasn't until supercontinents began to form, between 400 and 300 million years ago, that large volumes of soil – and therefore nutrients – stayed in terrestrial environments instead of being washed into the ocean.

New Zealand shows how mountainous continental coasts used to be

CLEMENTE DO ROSARIO/ALAMY

"Rivers transport nutrients in the sediments and start to promote nice environments for biodiversity to really kick off and start growing," says Salles.

Before the formation of supercontinents, he says, much of the world's landmasses had coastal mountain ranges such as we see today in New Zealand and Chile. This meant that, when it rained, sediment was swept into the marine environment, helping organisms there to develop, but leaving terrestrial environments comparatively devoid of life.

540

Number of million years of Earth's evolution modelled

With the formation of giant continents, more sediments remained on land, creating thick soils that promoted the development of flowering plants with roots.

"Flowering plants really began to peak between 150 million and 100 million years ago because a lot of sediments stayed on the land instead of flowing into the sea," says Salles.

The team found a near-perfect correlation between the rate of sediment flow and the explosion of new organisms due to evolution. For both marine and terrestrial environments, the greater the availability of nutrient-rich sediment, the greater the biodiversity. The converse was also true: when volcanism, plate tectonics or a drop in rainfall led to a reduction in sedimentation, within 5 million to 10 million years, biodiversity followed suit (*Nature*, doi.org/k629).

"I am impressed by how striking the correlation between sedimentation and both terrestrial and marine biodiversity is," says Alexander Skeels at the Australian National University in Canberra. "Usually in biodiversity studies, the patterns are complex and muddy."

While the model is based on reconstructing the past, it raises questions about the future, given how fast humans are driving land degradation and soil and nutrient loss, says Salles.

Human-driven disruptions of nutrient cycling through erosion and changes in sedimentation are likely to affect the land's capacity to host and evolve biodiverse communities, says Skeels.

"It's an interesting result and might have biological significance," says John Alroy at Macquarie University in Sydney, but it only shows that less sediment corresponds with fewer fossils, not necessarily less biodiversity. Major patterns of biodiversity in the fossil record are governed by preservation, he says. "Less sediments means less fossils, which means less biodiversity for researchers to be able to sample." ▮

Physics

How to pour water as quietly as possible

THE key to serving tea silently is creating a smooth flow.

Mouad Boudina at Seoul National University in South Korea and his colleagues filled a cylinder with water using a nozzle, while recording with a microphone and camera. Changing the nozzle's diameter or pouring from varying heights wasn't enough to make the process silent – both changes need to align to make the shape of the stream smooth and its fall quiet.

Pour from too low and there is noise. Go higher, and at a certain height, a stream of water breaks into rowdy droplets. But when poured from no more than one-third of this height, you get silence. The height depends on the diameter and shape of the nozzle, so would vary between teapots (*Physical Review Fluids*, in press). **Karmela Padavic-Callaghan**

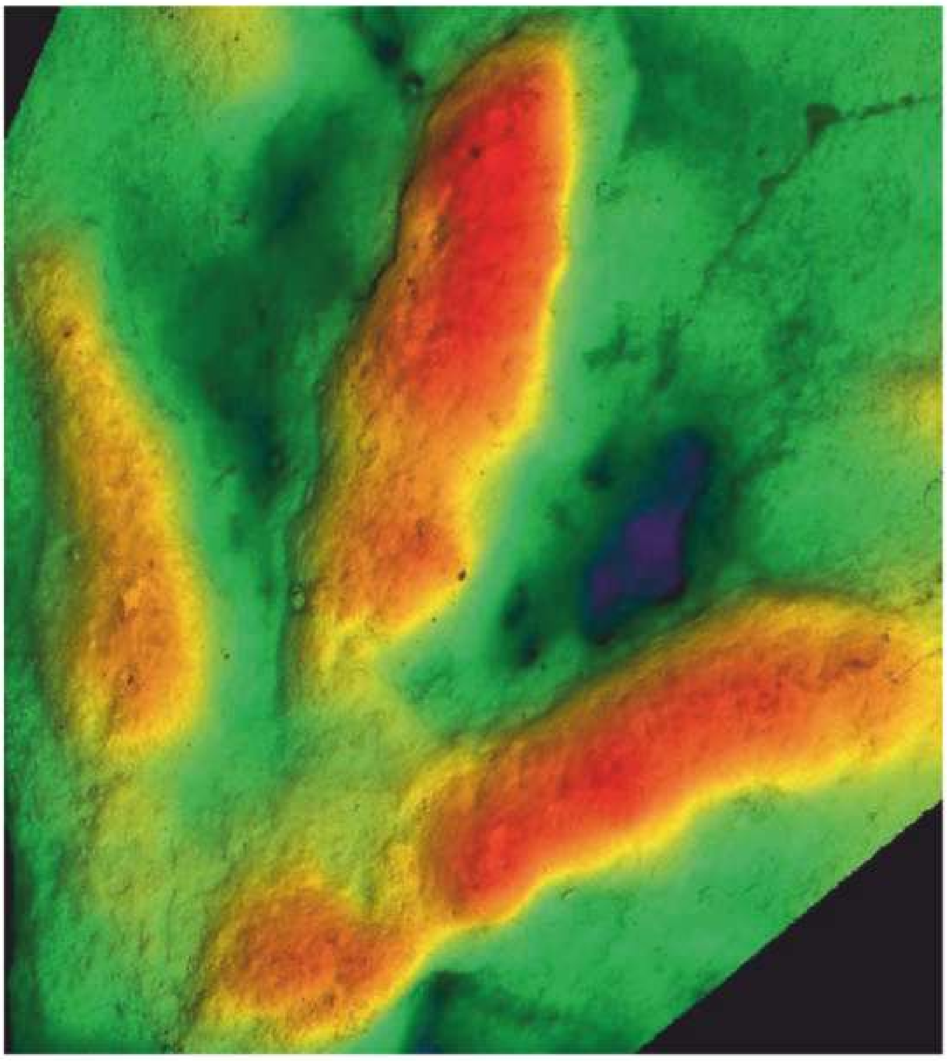
Astronomy

Tiny star harbours a colossal planet

ASTRONOMERS have found a world more than 13 times as massive as Earth orbiting a star nine times less massive than the sun, and our best predictions of how planets form say that this one shouldn't exist.

Suvrath Mahadevan at Pennsylvania State University and his colleagues found the world, called LHS 3154b, using the radial velocity method, which involves looking for wiggles in the position of a star as it is nudged by the gravity of an orbiting planet.

Their observations indicated that LHS 3154b circles its star – called LHS 3154 – once every 3.7 Earth days (*Science*, doi.org/k65z). "At this close in of an orbit, we've never seen anything like this," says Mahadevan. "We didn't believe that something so small, such a dinky star, could have such a large planet." **Leah Crane**



ABRAHAMS ET AL. 2023, PLOS ONE, CC-BY 4.0

Palaeontology

Birdlike prints left millions of years before birds existed

FOOTPRINTS preserved in stone in South Africa seem to have been made by animals with birdlike feet some 215 million years ago, long before the earliest known birds.

The earliest fossils recognised as ancestors of modern birds, including those of the famous *Archaeopteryx*, date back 150 million to 160 million years.

Miengah Abrahams and Emese Bordy, both at the University of Cape Town, South Africa, studied a diverse collection of footprints, including the one shown above, at a site called Maphutseng, as well as casts and sketches of prints from four other sites in Lesotho.

The researchers focused on *Trisauropodiscus*, a name given to distinctively shaped three-toed footprints left by animals whose exact identities remain a mystery.

The prints could be separated into two main groups based on their shape, one distinctly birdlike.

"Our birdlike ones have a big, wide splay in the outer digits, like a waterbird, and the toes were incredibly slender, with the central toe not really projecting far forward," says Abrahams.

The general shape of the footprint is comparable with other fossil bird tracks and modern bird tracks, she says.

The second group had more rounded, robust and elongated toes that were less splayed out. They resembled another type of footprint, known collectively as *Anomoepus*, which are attributed to dinosaurs with birdlike hips (*PLoS One*, doi.org/k628).

The discovery suggests that birdlike feet evolved much earlier than the first birds, and may have evolved independently in other animal groups. **Ryan Truscott**

Really brief

MARK GARLICK/SPL/ALAMY

Key molecule may form on space ice

A key amino acid, called carbamic acid, could be created via reactions on clumps of ice in deep space. Amino acids are the building blocks of proteins, and vital for life on Earth. Meteorites or asteroids (pictured above) could then have carried the substance to planets (*ACS Central Science*, doi.org/k653).

Penguin takes thousands of naps

Male chinstrap penguins (*Pygoscelis antarcticus*) have more than 10,000 naps a day while incubating their eggs – but each lasts for just 4 seconds. This fragmented sleeping pattern allows them to keep a watchful eye for seabirds such as skuas that prey on the eggs (*Science*, doi.org/k654).

Bitcoin transaction has huge water use

About 16,000 litres of clean water is used per bitcoin transaction, enough to fill a small swimming pool. A lot of that is down to generating the electricity that powers cryptocurrency transactions, such as in gas or hydroelectric plants (*Cell Reports Sustainability*, DOI: 10.1016/j.crsus.2023.100004).

Perpetual lunacy

The extraordinary new **C1 Moonphase** from Christopher Ward. A watch that tracks the moon for 128 years – without missing a beat. With an aventurine glass dial infused with copper oxide to represent the night sky. And a 3D 'moon' sculpted from Globolight© – a luminous ceramic – that precisely follows the real moon's journey across the sky. A watch this advanced can cost up to £45,000. But the C1 Moonphase starts from less than £2,000. As someone once said, you don't have to be mad to work here...

Do your research.

Christopher
Ward

christopherward.com

SCAN ME

Views

The columnist
Chanda Prescod-Weinstein on the Unruh effect p22

Aperture
A new exhibit illuminates life in tropical forests p24

Letters
On the search for what makes us human p26

Culture
Music inspired by the acoustics of glacial caves p28

Culture columnist
Jacob Aron picks the best board games of the year p30

Comment

Vanishing past

It has been over 100 years since the US began protecting its ancient sites from development, but they remain vulnerable to politics, says **Rachel Morgan**

ELAINE KNOX

IN OCTOBER, the US Department of Homeland Security made an urgent announcement. New barriers and roads were needed along the Texas-Mexico border – but construction was impeded by federally mandated surveys and permits. These protect the environment and archaeological sites. They also take time to complete. To speed construction, the Biden administration waived compliance with 26 federal laws, eight of which regulate archaeological and/or sacred Indigenous sites.

In 1888, it was looters, not governments, who were barrelling through the past. Anthropologists Alice Fletcher and Matilda Stevenson knew the looters were winning. They proposed legislation to preserve US archaeological sites on public lands. Their bill was essential – and dead on arrival. Many appreciated the ruins' beauty but there were votes to consider and things to build. Unprotected, America's archaeology began to vanish.

The Papal States had enacted preservation legislation in 1819, England and Ireland in 1882 and France in 1887. The US, meanwhile, was watching the past disappear.

In 1892, years of preservation advocacy paid off when president Benjamin Harrison preserved 195 hectares around Arizona's Casa Grande ruins. As the US's first archaeological preserve, it was a victory. But ancient sites elsewhere remained defenceless.

Slowly, preservationists succeeded in protecting single places of antiquity, such as Ohio's Serpent Mound, which dates to around 1100. But this didn't prevent looting of Colorado's cliff dwellings, which date from the 7th to the 13th century. At sites across the US, visitors filled their pockets with artefacts.

Comprehensive preservation legislation was needed. The 1906 Antiquities Act marked the first general protection of US historic properties. The National Historic Preservation Act (NHPA), which urged harmony between preservation of the past and future development, followed in 1966.

Thousands of archaeological sites have been preserved through section 106 of the NHPA, which requires federal entities to consider the potential effects of their actions on historic properties prior to development. But by sleight of hand, protections of the past are now being weakened. An act introduced in March could, if passed, exempt many oil and gas drilling projects from section 106 compliance, endangering multiple potential sites.

There is also good news. In June, a ban on new oil, gas and mining development around New Mexico's Chaco Culture National Historical Park was announced. In August, the Biden administration established the Baaj Nwaavjo I'tah Kukveni – Ancestral Footprints of the Grand Canyon National Monument in Arizona, protecting some 400,000 hectares from uranium mining, following a decade of Indigenous advocacy.

Et voilà! The past is preserved. Like other national monuments created by the Biden administration, these protections are a cause for celebration – for now. It is worth remembering that president Barack Obama's 2016 designation of Bears Ears National Monument, preserving thousands of Utah's sites, was celebrated too. But with a wave of the executive pen, president Donald Trump dramatically reduced the area of the monument. It wasn't restored until 2021. Preservation by executive action is a precarious solution, susceptible to the political agenda of the presidency.

And it would be a mistake to assume that existing legislation will hold fast. Protecting the past means paying close attention to the swings of the preservation pendulum as efforts to speed development threaten protections of archaeological sites. Because once gone, no magic words will restore the past. ■

Rachel Morgan is an archaeologist and author of *Sins of the Shovel*

Field notes from space-time

Otherworldly fields I have been revisiting the Unruh effect, a beautiful, strange concept born from quantum field theory in curved space-time, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her most recent book is *The Disordered Cosmos: A journey into dark matter, spacetime, and dreams deferred*

Chanda's week

What I'm reading

I really love Airea D. Matthews's new poetry collection, Bread and Circus.

What I'm watching

The ending of series 3 of The Morning Show *was pretty disappointing.*

What I'm working on

Writing two books at once – while keeping up with research – is hard.

This column appears monthly

I HAVE been pretty obsessed with space-time this year. Thankfully, I am a theoretical physicist and, in principle, this is my day job. But the more time I have spent returning to my roots with it, the stranger the whole thing has started to seem to me. As I wrote in an earlier column, it is actually pretty hard to explain this strange merger of what are ostensibly familiar, but actually incredibly distinct, concepts.

In your everyday life, you generally experience space and time as separate phenomena. Then along comes the physicist with some thought experiments about clocks, trains and even the soap opera *Emmerdale*, and we have to revisit the entire universe with a different perspective.

My work as a scientist is, in some sense, a practice of repetition. I am often going over the same ideas, again and again, but each time I have a slightly different question in mind. This year's focus on space-time was driven by the difficult question of how to help people have intuition for this concept without resorting to equations.

I also find myself in a regular state of repetition because my research has a tendency at any given time to go more strongly in one of two directions: sometimes it is more general relativity (space-time) and sometimes it is more quantum field theory (particle physics). When I spend a lot of time on the one, the sharpness of my understanding of the other starts to slip. So, I pick up a book to remind myself of the things I thought I knew. Each visit is different from the last, though.

As a case in point, this year, my brain unexpectedly took me in the direction of revising my relationship to the mathematical framework for particle physics – quantum field theory (QFT) – simultaneous to my extended meditation on relativistic notions of space-time. The end product was that I began to yearn for something that drew the two together. And so, for the first time in nearly 10 years, I picked up my books on quantum fields in curved space-times, once a topic I knew so well that I passed an oral examination on it during my PhD.

It felt so otherworldly! I had to remind myself of its significance and value. When we are dealing with particle physics, we need to take quantum mechanics into account, along with special relativity, because particles are very small and often fast-moving.

> "You may not have heard of the Unruh effect, but you will almost certainly have come across Hawking radiation"

QFT is the framework that allows us to do both simultaneously. In this picture, we are in a flat space-time (no fun with curvature!), but taking quantum mechanics and the finite speed of light into account simultaneously requires reimagining what, exactly, a particle is. Relativistic quantum mechanics evolves into the mathematical picture known as QFT. In this scenario, the fundamental concept of the particle is replaced by a notion of a field acting on the vacuum.

There is no simple way to intuitively understand a field, in my opinion. But there are examples we can use to try. For instance, temperature as it varies throughout a room is an example of a field. At each point, the temperature is a little bit different. The information together is a field of temperature. Similarly, the sun is exerting a gravitational field on everything in the solar system.

QFT doesn't take gravity into account because it was developed for scenarios where we don't need it. And the concept evolved quite distinctly from general relativity for a long time. But eventually, physicists began to wonder how to construct a sense of QFT in a non-flat space-time – a curved space-time where gravity can't be ignored. This is how QFT in curved space-time was born. Andbecause I have limited space, I will simply share my favourite result from this formulation: an accelerating observer will observe the presence of particles where a non-accelerating observer sees none! The two observers won't agree on whether they are in an empty vacuum.

This phenomenon is known as the Unruh effect. It is likely that you have never heard of it, but you will have almost certainly heard of a related concept: Hawking radiation. Stephen Hawking realised that when we consider something like the Unruh effect near a black hole's point of no return – the event horizon – then effectively a black hole could be said to radiate particles.

The Unruh effect is a beautiful, wonderfully strange idea, and it is also the one that underpins the name of this column. For years, I hadn't thought in any serious way about it, even though there once was a time when I could write out the equations that describe it purely from memory.

The hard lesson I have learned as a physicist is that knowing physics isn't about having it all memorised, but rather about knowing how to come back to what I thought I knew, and revisit it with a fresh perspective.

EMERGENCY SURGERY

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

HELP SUPPORT OUR MEDICAL TEAMS TODAY

Jessica Comi (left) and MSF surgeon Dr Federica Lezzi extract a bullet from a patient shot just above the knee during fighting in the Sudanese capital. Bashair hospital, Khartoum, 13 May. Photograph © Ala Kheir/MSF

JESSICA COMI IS AN OPERATING THEATRE NURSE WHO WORKED FOR MSF IN KHARTOUM, SUDAN.

"We arrived in Khartoum on a Monday and started operating at noon the following day. The first week was incredibly challenging.

Every time we heard explosions, we got ready for a mass casualty incident – a situation where lots of wounded people arrive at the same time. You never know if it will be 20 or 40 or 100 patients. One day, 127 patients arrived in a short space of time after a series of explosions.

Very quickly we were inundated with wounded men, women and children. Seventeen people were dead on arrival. The emergency room was full, the two operating theatres were full. In one theatre, we were trying to manage the most complex cases; in the second, we were working on cases that were a bit less complicated. That day, we ran the operating theatres until four or five in the morning. We worked non-stop.

War surgery is complicated. Working with wounded patients brings a lot of challenges and, if you aren't used to doing this type of surgery, it can be especially difficult. You need to know the potential risk for a patient if they are not treated immediately – risks such as infections or losing a limb or haemorrhaging. Bullets and shrapnel are dirty and they create massive wounds, so in a war zone you treat every single wound as already infected. These injuries are complex and you need to act quickly. Our team was experienced and that expertise made a big difference.

Depending on the kind of wound, some patients need multiple surgeries and can take many days to recover. Others may need even longer treatment – taking weeks or sometimes months.

As the conflict continued and more people heard that the hospital was open, we started to see more patients, particularly women and children.

I have worked a lot in war zones, and this was probably my most challenging assignment. But it was very special how the team worked through the challenges together. You could feel that we were all working for one reason – and that was to save lives."

WE CAN'T OPERATE WITHOUT YOU

Every year, MSF teams carry out tens of thousands of surgeries. From treating war wounds to emergency caesareans and reconstructive surgery, our surgeons are at the frontline of our lifesaving care.

In 2022, MSF teams around the world conducted more than 118,000 major surgeries. In the places where we work, demand for surgical services has never been higher. We need your support now more than ever to provide people with lifesaving medical care.

Please donate today to support our emergency medical teams.

£20	can provide three patients with antibiotics to prevent infections after surgery
£190	could pay for emergency splints to immobilise injured limbs for 22 patients
£84	covers the cost of an MSF surgeon working in a hospital for one day

THANK YOU

100% of the funding for our work comes from private donors. It's your support that enables us to provide emergency medical care.

DONATE NOW

CALL 0800 055 79 84

Or search 'MSF APPEAL' to make an online donation

YES, I would like to support MSF's medical teams

I WOULD LIKE TO MAKE A DONATION OF £

Please make your cheque/charity voucher payable to Médecins Sans Frontières UK

OR ☐ Please charge my VISA/Mastercard/Amex/CAF card:

Cardholder name

Card number ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Expiry date ☐☐/☐☐

Signature ______ Today's date D D / M M / Y Y

Title Forename(s)

Surname

Address

Postcode

Telephone

Email

HEAR FROM MSF BY EMAIL 102796

☐ Sign up to our monthly email, Frontline, which provides first-hand accounts of our work. You will receive Frontline, occasional emergency appeals, requests for donations and event invitations.

Charity Registration Number 1026588

ARE YOU A UK TAXPAYER?

giftaid it

If so, you can make your gift worth 25% more at no extra cost. Please tick the box below.

☐ I wish Médecins Sans Frontières (MSF) to treat all gifts in the last 4 years, this gift and all future gifts as Gift Aid donations. I am a UK taxpayer and understand that if I pay less Income Tax and/or Capital Gains Tax than the amount of Gift Aid claimed on all my donations in that tax year, it is my responsibility to pay any difference.

Date D D / M M / Y Y Y Y

NB: Please let us know if your name, address or tax status changes, or if you would like to cancel this declaration, so that we can update our records.

RESPECTING YOU AND YOUR PERSONAL DATA

Your support is vital to our work and we would like to keep you informed with first-hand accounts from our staff and patients about the lifesaving impact your support is having, from combatting epidemics to providing emergency surgery.

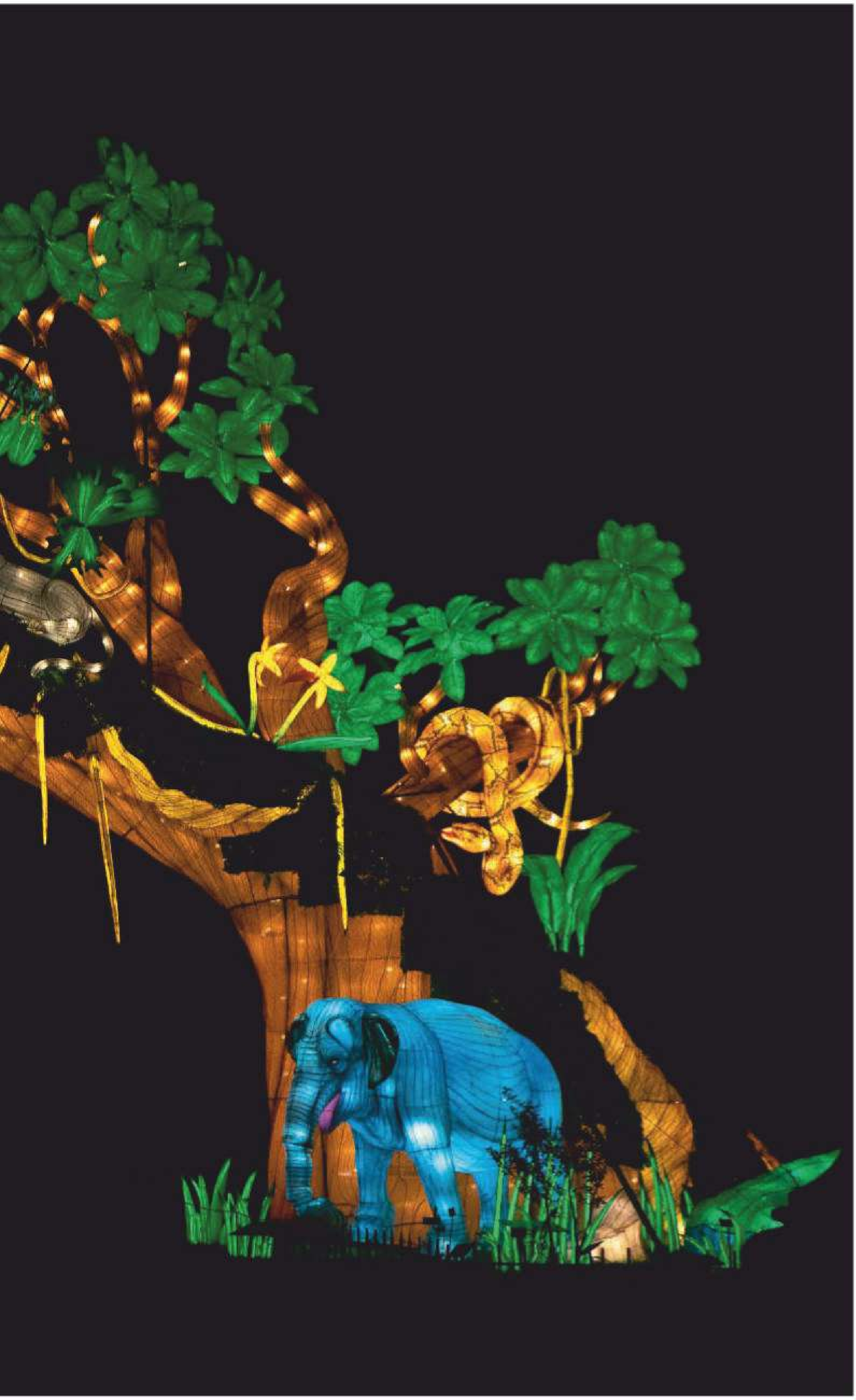
We won't allow other organisations to have access to your personal data for marketing purposes and we won't bombard you with appeals.

By supporting MSF, you will receive our quarterly magazine Dispatches, event invitations and occasional emergency appeals with requests for donations by post. You can change how you hear from MSF UK by emailing **uk.fundraising@london.msf.org** or calling **020 7404 6600**. Visit our privacy notice for more: **msf.org.uk/privacy**.

Please fill in this form, place in an envelope and return postage free to: **FREEPOST RUBA-GYZY-YXST, Médecins Sans Frontières (MSF), Bumpers Way, Bumpers Farm, Chippenham, SN14 6NG.** Alternatively, you can phone **0800 055 79 84** (open 8 am – 1 pm seven days a week) or make your donation online by searching **'MSF APPEAL'**.

MSFR0048

CHINA LIGHT FESTIVAL BV



Illuminating

National Museum of Natural History, France

TROPICAL forests have rarely looked so dazzling.

This is the entrance to the Jungle en voie d'illumination ("Jungle on the way to enlightenment") exhibition, organised by the National Museum of Natural History in France. It is designed to showcase the unique diversity of the world's tropical forests through a series of majestic light installations that focus attention on an array of animals and plants.

Adorning the illuminated arch are several works that offer a glimpse of what is in store in the first zone of the tour: India. An Asian elephant, tigers, a black panther, langur monkeys and a reticulated python – just a few of the country's wild inhabitants – can be seen within the luminous forest display, some peeking out of its shining leaves.

From there, the exhibition goes on a journey of discovery to the forests of Borneo, New Guinea, the Amazon (the largest of these landscapes and home to 10 per cent of all biodiversity) and Madagascar, before ending in central Africa – while also raising awareness of the need to protect these special landscapes and habitats.

The exhibition will be at the Jardin des Plantes in Paris until 21 January 2024. ▮

Gege Li

Editor's pick

On the search for answers to the human condition

25 November, p 28

From Joseph LeDoux, New York University, US

In her review, Susan Blackmore says she has learned much from my book, but complains there are already many similar accounts of ontological realms, and that I don't cite them. I do, in fact, cite the ones she mentions, as well as others, and explain why mine is different. My focus is less on cataloguing which realms are present in different animals and more on how our four realms (biological, neurobiological, cognitive and conscious) make us humans what and who we are from moment to moment.

On the question of consciousness, she says I did a great job of laying out the groundwork, but don't get to the deep questions of subjective experience. I intentionally emphasised preconscious processes that take humans to, and across, the finishing line for the various kinds of consciousness we subjectively experience (autonoetic, noetic, anoetic). The virtue of this is that these preconscious processes can be studied similarly in other animals, especially other mammals, to explore the kinds of consciousness they might possess, even if we can't prove that they also cross the finishing line.

From Greg Nuttgens, Porthcawl, Bridgend, UK

Blackmore describes three approaches to explaining the so-called "hard problem" of consciousness. There is a fourth: that there is no hard problem at all. Though many people still appear to believe that human brains are in some way qualitatively different from those of other animals, I don't. Isn't a dog or a crow conscious of itself and its environment? We have big brains, with spare capacity that allows us to ruminate on our existence. That is the only difference.

Let's see the positive in weight-loss drugs

18 November, p 8 and p 48

From Geoff Harding, Sydney, Australia

The weight-loss injection Wegovy, if it lives up to expectations and is used widely, can set the imagination racing on possible consequences. Improved health will surely increase average longevity, with implications for pensions and care of the elderly. Lower average passenger weight will result in lower fuel consumption and lower emissions for aircraft. If progress to obesity is averted, fewer purchases of larger clothing will be necessary. On losing weight, many individuals may find it far easier to exercise more, with significant health benefits. The consequences may well affect some industries negatively, particularly those in food production, but the positive consequences are paramount.

Alien first contact is probably best avoided

Leader, 25 November

From Maggie Cobbett, Ripon, North Yorkshire, UK

You say the search for alien life needs strong guidelines to be sure of what is really out there. Among those guidelines, I would include a caveat: be careful what you wish for. Although my strongest claim to scientific erudition is a barely scraped O level qualification in biology many years ago, I have always had an uncomfortable feeling that alerting any alien civilisations to our existence wouldn't bode well for us.

The history of humanity has proved over and over that Indigenous populations are treated with contempt by those who discover them, and are at best ruthlessly exploited, at worst, exterminated. This may prove to be a universal truth in the fullest sense of those words and we might be wise to keep a very low profile.

We have messed up the carbon cycle long term

18 November, p 11

From Fred White, Nottingham, UK

Given the more than 70 per cent reduction in foraminifera shell thickness since 1872 due to ocean acidification, the idea that global temperatures will stop rising in the short term if we manage to get to net zero seems optimistic. These shells are an oceanic carbon sequestration engine that will need alkalinity levels to return to historical norms, which might take over a century, if not a millennium.

Humans are well-equipped to deal with uncertainty

11 November, p 30

From Jonathan Wallace, Newcastle upon Tyne, UK

In her review of Naomi Alderman's *The Future*, Sally Adee makes the surprising comment that "we are uniquely ill-equipped by evolution to handle uncertainty". Surely the opposite is true. Our success as a species thus far is based on our enormous flexibility and adaptability that have allowed us to spread everywhere. Time will tell whether we manage to survive the environmental crises of our own devising that we are plunging into, but our proven ability to rise to new challenges perhaps gives us the best chance of doing so. Sadly, many other species – those less able to live outside the narrow parameters of their niche – won't survive if we fail to put a brake on our harmful misuse of the planet.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, 9 Derry Street, London, W8 5HY will be delayed

Why do we waste so much water in toilets?

26 August, p 36

From Frida Inta, Westport, New Zealand

Graham Lawton wrote about the growing worries that a stable supply of clean water around the world is threatened. The flush toilet was the beginning of the downfall of modern society. To mix human faeces with 4 litres of water a few billion times a day is the most heinous rebuff to nature. Never mind that it is treated via costly infrastructure, it is still a colossal degradation of clean water. No municipal treatment will restore the water to its former quality. I have used a composting toilet for many years now, and composting (or municipal biogas) is the only feasible solution for human faeces.

There are better ways to get extra lithium

18 November, p 22

From Scott Mendham, Sydney, Australia

The fly ash left after burning coal only contains a small proportion of lithium. If the ash is used for the extraction of this metal, what will happen to the other 99.8 per cent of this waste, which includes arsenic, lead, mercury, radioactive elements and added chemicals used in the extraction? Fly ash is a major environmental issue, but mining it for 0.2 per cent of its content could make the problem worse, especially when recycling used lithium would be a superior alternative to boost supplies. ▮

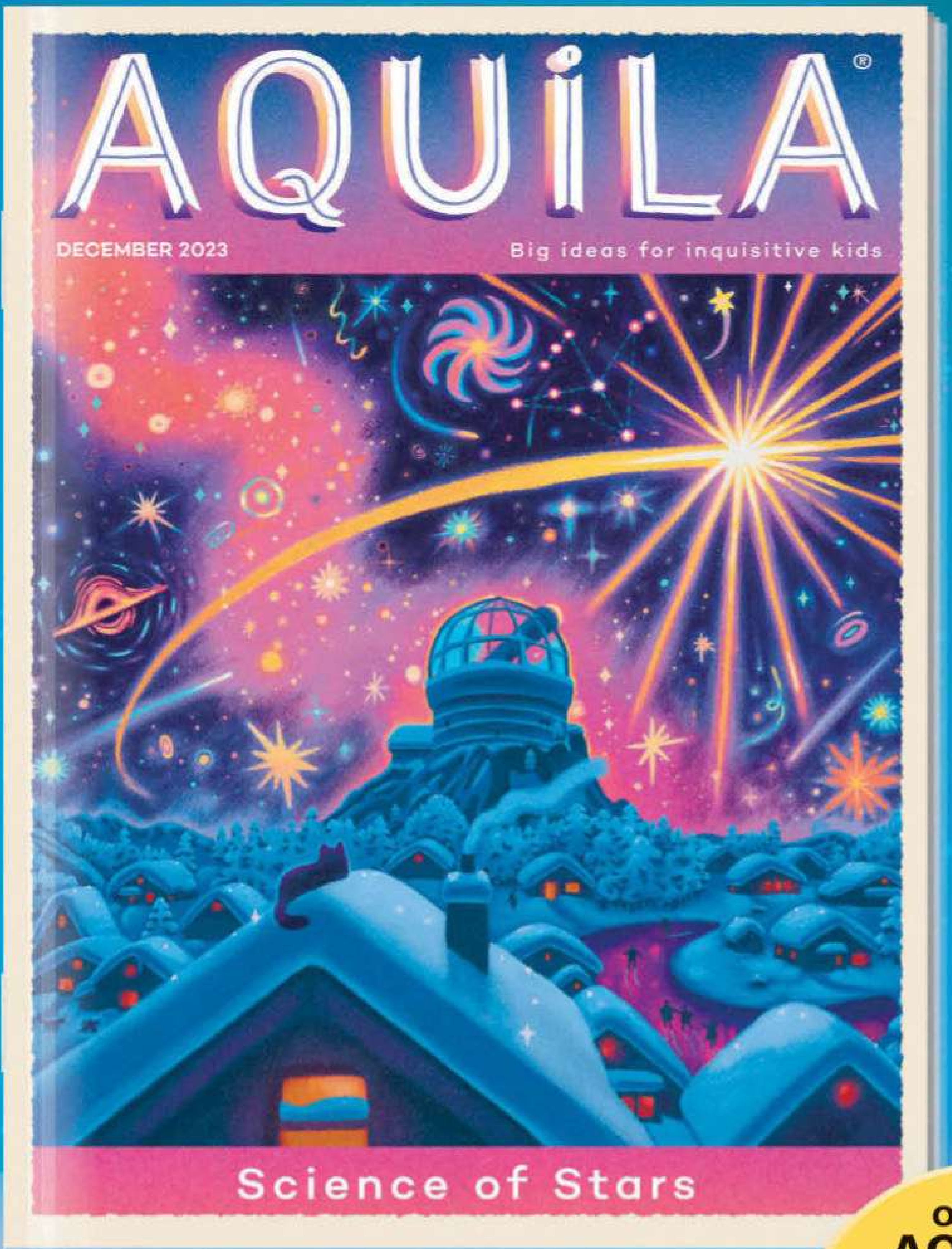
For the record

▮ **In our look at links between Huntington's disease and IQ (25 November, p 10), a study in August focused on young adults who were alive, while research supporting toxicity of the Huntington's protein involved animal models and lab-grown neurons.**

30 fabulous years of AQUILA

A Cosmic Christmas Gift!

The perfect magazine for sparkling young minds...



Children love AQUILA's fascinating monthly topics. Packed with science facts and intriguing puzzles, the magazine is so well written that many adults love reading it too.

The December issue: Science of Stars – are we made of stardust? AQUILA investigates star lifecycles, the mystery of Sirius B and much, much more.

- **Great reading for curious kids of 8–14**
- **General knowledge, Science & Arts**
- **Philosophical & puzzling**
- **Big ideas & Creative fun**

"It informs, it educates, it entertains..."

The British Society of Magazine Editors Awards
Youth Winner 2021 & 2022

AQUILA.CO.UK / 01323 431313

ORDER AQUILA now to arrive for CHRISTMAS

Open Christmas Day and Gift Message

Scan me

Ice music to melt hearts

Research into the acoustics of Svalbard's glaciers and caves is fundamental to composer Erland Cooper's latest works, finds **Arwa Haider**

I FIRST met musician, composer and artist Erland Cooper outside London's Barbican Centre in late spring. He had been standing for 12 hours next to his 2.4-metre-high ice sculpture, *Glacier*. This thawing, crystalline monolith reflected the climate change themes and fragile beauty of his fourth-and-latest album, *Folded Landscapes*.

"It was a kind of slow protest... a gentle way to bring conversations together," explains Cooper when we next meet, some months later. "I love that people just came up and sat beside me, picked at it, talked about it."

We are now in Cooper's basement studio, where another ice block looms amid his collection of digital technology and vintage synthesisers. The ice contains frozen hydrangea and thistles, plus a channel designed to hold a hydrophone mic, used to capture underwater audio – its drip-drip melting forms a rhythmic backdrop to our conversation.

Cooper's work is imbued with child-like wonder, but also a lingering, worldly reflection. Does he consider himself an activist-artist? "I don't like to be divisive. I like people to come up with their own views and engage in conversation rather than make statements," he says.

"And this is an opportunity to celebrate and cherish the natural world. [Musician/artist] Brian Eno said art has the ability to make you feel something. Generally, when you feel something, you make changes. Music is a really good catalyst for that."

ALEX KOZOBOLIS

Erland Cooper next to his ice sculpture, *Glacier*

Folded Landscapes emerged through Cooper's typically playful experiments. Its seven movements were recorded with the Scottish Ensemble chamber orchestra, across temperature shifts spanning the sub-zero and a sweltering studio, with the audio master tape exposed to the elements and sun-scorched on 19 July 2022, the UK's hottest day in history.

"I took these incredible virtuoso musicians into a factory in Glasgow and recorded them in sub-zero temperatures," he grins. "They all had fingerless gloves and big jackets, and were just beaming, because it was something different. It was a process to really get under the fingernails of rising temperatures. The first one to four movements are austere, a steep glacial ascent. Then it's a toboggan ride of hope down the other end.

"Over the seven movements of thawing, the fidelity of the audio is getting worse, but the music arguably becomes more hopeful. There's this kind of Scottish classical ceilidh on the sixth movement, and I've fond memories of sweating in the studio as they were vigorously playing."

The album also features guests such as UK poet laureate Simon Armitage, while its heady fifth movement samples familiar voices, including Greta Thunberg, alongside a 1970s news report delivering very similar ecological warnings. "That moment is not about those personalities, it's actually just about noise – that echo chamber of opinion, which can be quite antagonistic," says Cooper.

Secret soundings

He delights most in "the magic of the everyday", whether it is around his London flat or his birthplace of Orkney in Scotland, which recurs throughout his work, including an earlier triptych of albums. Cooper and his siblings were raised by scientist parents. While he never studied music, at weekends he would sneak into the school where his father worked to teach himself to play the piano and decipher tape machines.

"Science has always played a major role in this feeling of exploration," he says. Increasingly, he has gravitated towards collaborative work, both with other people (in previous outfits including The Magnetic North and Erland & The Carnival) and with nature itself. "My music's always got a sense of place," he says. "How can I dig into the soil a bit harder?"

Cooper literally dug deep for another project, *Carve the Runes Then Be Content With Silence*, "planting" the score and the only tape of his first classical album at a secret spot in Orkney, with just treasure hunt clues to retrieve it.

After a year and a half marinating in the soil, the tape was finally unearthed by two fans and is currently being displayed on a "drying out" tour across UK independent record shops. It will be premiered as part of a Barbican concert in June 2024. In an on-demand era, it feels radical to really wait to experience something. "This memory of something suddenly became the most precious thing," says Cooper.

His latest release, in May, was a piano version of *Folded Landscapes* – this time applying the echo captured in Norwegian glacial caves to the elegantly minimal melodies. Here, he uses impulse response data (in this case, the reaction of a dynamic environment in relation to external change) collected from Svalbard by a team of European scientists for their own studies measuring the diversity of acoustic climates, which depend on the morphology and dimensions of the caves. Cooper recorded his piano using an ice-encased hydrophone, trying to gauge how the ice "hears" music.

"Instead of taking the piano to

a glacial cave in Norway and recording there, could I take the reverb of the cave and bring it back to my studio? Technology allows us to do that," he says.

One of the scientist team, Pawel Malecki, sent me an email expressing his delight at being contacted by Cooper for this album. "This isn't the first time someone has shown interest in our impulse responses, however, Erland's idea undoubtedly stands out for its uniqueness and creativity," he wrote. "Using the acoustic properties of caves for producing music adds a level of immersion and symbolic connection to the caves.

> "Cooper never studied music, but he sneaked into his father's school to teach himself the piano"

"Above all, I'm thrilled that the acoustics of northern environments are gaining attention. Our work has primarily been of interest within specialised scientific circles. Now, with projects like Erland's, a broader audience will get to experience and appreciate the captivating acoustics of the Svalbard glaciers and caves."

For now, Cooper sets up the hydrophone and sound desk – and that is how I end up reciting Shakespeare to an ice sculpture. When Cooper replays my voice – filtered through frozen water and Arctic cave echoes – it sounds coolly haunting, transformed into something or someplace else. "That's a mic-drop moment," he smiles. "Really, living with the natural world is a duet in itself." ▮

Arwa Haider is a writer based in London

Scientific harmonies

Our resident experts **Bethan Ackerley** and **Tim Boddy** round up the best science-inflected music albums of 2023

The Fall: **Komorebi**

In this high-concept, anime-inspired album, Komorebi becomes her alter ego, Kiane, an alien who visits Earth on a voyage of self-discovery. Transported by delicate vocals and the sweeping orchestration, I felt punch-drunk by the end. *Bethan Ackerley*

Complete Mountain Almanac: **Complete Mountain Almanac**

Rebekka Karijord and Jessica Dessner have put together something remarkable with this album that started as a climate change project, but morphed after Dessner's breast cancer diagnosis. It is a haunting work on nature's healing cycles. *BA*

The Universe's Wildest Dream: **Marcus Strickland Twi-Life**

The wonder of our planet and the cosmos is threaded through every track of this Afrofuturist album. Through his playful jazz, Marcus Strickland celebrates Earth as a uniquely perfect cradle for life – and argues this should spur action on climate change and inequality. *BA*

Weedkiller: **Ashnikko**

Full of swagger and rage, Ashnikko's debut studio album is a caustic rebuke of our times. Set in a world where super-intelligent machines have wrecked nature, this revenge narrative is weaved with themes of parasitism and bodily autonomy, particularly in the stand-out track *Worms*. *BA*

The Complete San Francisco Moog 1968-1972: **Doug McKechnie**

Doug McKechnie was one of the first to get access to a modular Moog synthesiser. This collection brings together his recordings from a crucial moment in music history, when electronic instruments were beginning to show their potential. *BA*

Blómi: **Susanne Sundfør**

In *Blómi* ("be in bloom", from Icelandic), Susanne Sundfør has created a complex set of tracks touching on Norse mythology, family and the climate crisis. Above all, though, it is an ode to her daughter and to becoming a mother. The sonic palette is all-encompassing. Take *leikara ljóð*, which starts with birdsong, adding rhythmic hand claps followed by harmonised chants, rising to a crescendo. It is timeless and expansive – a beacon of hope amid an overwhelming world. *Tim Boddy*

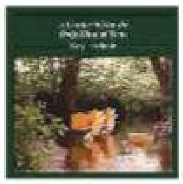
Follow the Cyborg: **Miss Grit**

This debut album is timely with its themes of AI and machine learning. Miss Grit (aka Margaret Sohn) uses the trope of a cyborg achieving awareness to explore self-hood, including gender identity. *Syncing* is the most beautiful break-up track you are ever likely to hear – between a cyborg and its creator. *TB*

Perfect Picture: **Hannah Diamond**

Hannah Diamond continues to play with exaggerated femininity encased in bubble-gum pop. In her strongest work to date, critiques of online culture and self-perception feel focused, aware and mature. *Affirmations* is the best song not on the *Barbie* soundtrack. *TB*

A Ladder Is Not the Only Kind of Time: **Benjamin Tassie**



Benjamin Tassie explores the industrial heritage of Sheffield, UK, in this highly original album that draws on the city's rich past through three new water-powered instruments, made with instrument designer Sam Underwood. These were taken to the Rivelin valley, which has been shaped by watermills. Tassie recorded there, and this relationship gives the river Rivelin its voice back, evoking a time of thriving industry with delicate, captivating results. *TB*

No Fixed Point in Space: **Modern Nature**

"It's a lot to take in... It's impossible to see," sings Jack Cooper on the serene track, *Ensō*. Cycles of growth and rebirth pulse through the trio's third album, reflecting their move from rock to jazz-folk. Visions of English countryside, of dusk and dawn, burrow into your psyche in this intriguing slow burner. *TB* ▮

Game on!

What would you do to combat climate change if you were a world superpower? That's just one of the challenges set by 2023's best board games, writes **Jacob Aron**

MARTIN LABBE/HACHETTE BOARDGAMES

***Sky Team*'s secret manouevres make for nail-biting action**

CHRISTMAS is a perfect time for sitting down with friends and family around a board game, whether it is an old favourite with half the pieces missing or something hungrily unwrapped and brand new. Here are Culture's recommendations for 2023's best new board games. Enjoy!

Daybreak, 1-4 players

Imagine solving climate change in an evening. That is the hopeful prospect offered by *Daybreak* (CMYK), which casts players as world powers attempting to cut carbon emissions without throwing their populations into crisis or taking too long and boiling the world.

Playing as either the US, China, Europe or the rest of the world (referred to as the Majority World), you start the game with 1.2°C of warming above pre-industrial levels, and a board representing societies mostly built on fossil fuel consumption and greenhouse gas-belching ways of living – pretty much as now.

Over six rounds, players must work first at a global level, agreeing to tackle international projects such as ecological protection or nuclear fusion, and then at a local level to green their economies. This is done with cards detailing everything from climate finance to walkable cities, which you can combine and activate in different ways to remove carbon-producing elements for your individual player board.

You will also face various crises, which you can attempt to mitigate, and any carbon emissions you fail to quash will increase the global temperature and risk destabilising ecosystems.

What is incredible about *Daybreak* is this could easily be a very dull, educational game, but instead it is a thrill. While every card comes with a QR code you can scan to learn more about the science and policy behind it, you are more likely to spend time studying the gorgeous art and figuring out the best way to combine your cards. Success isn't assured, but when you pull it off, it is a rush, and an optimistic boost for the real world, to boot.

> "You're in a cockpit as pilot and co-pilot, with one job: land the plane. But you aren't allowed to talk to each other"

Earthborne Rangers, 1-4 players

From a world fighting climate change to one that long ago succeeded, *Earthborne Rangers* (Earthborne Games) is set in the far future, when humanity has rewilded the planet and now aims to live in harmony with nature.

It is impossible to win or lose *Earthborne Rangers* – instead, you should think of the game more as an open-world, narrative engine for telling cosy science-fiction stories in the style of *Wayfarers* writer Becky Chambers.

Everything in *Earthborne Rangers* is powered by cards, from the locations you visit to the flora and fauna you encounter along the way, and even your own abilities and equipment. Together, these create a world that can respond to your actions, as every time you attempt a task, such as exploring locales or avoiding predators, you trigger other actions on other cards.

These have the potential to help or harm you, but can also be entirely neutral, such as a predator attacking its prey because they happen to be in the same place.

Executing all of these systems can be a bit fiddly – this isn't a title I would recommend for people without some experience of board games under their belt – but when it works well, it is amazing just how evocative it can be.

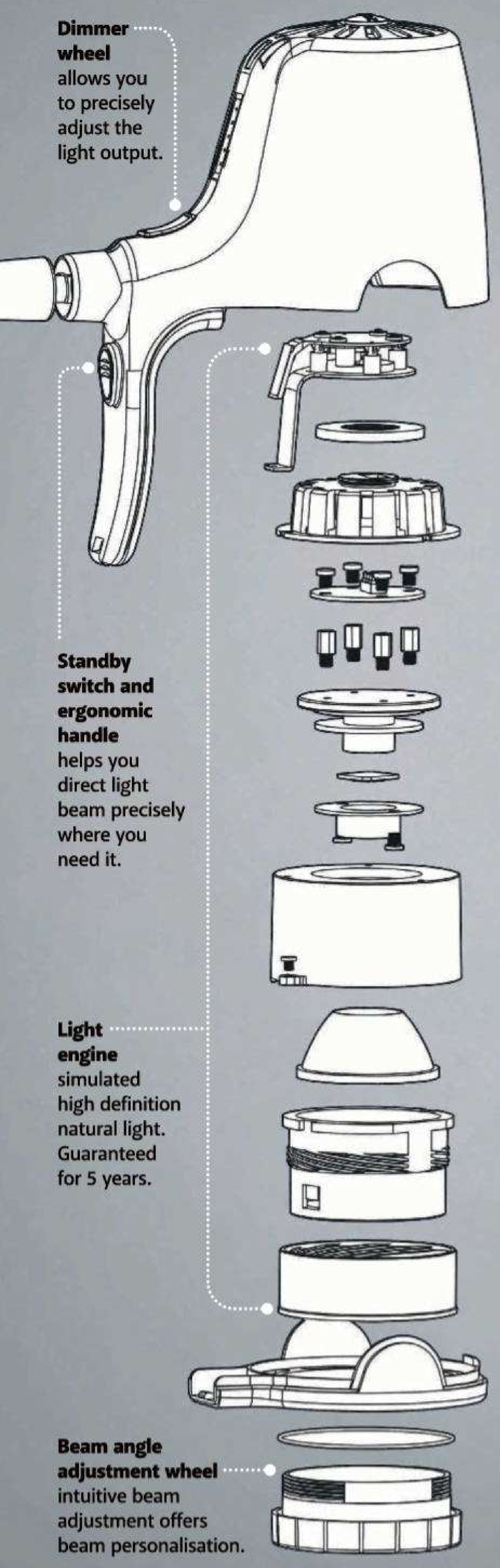
Sky Team, 2 players

You are in an aeroplane cockpit as pilot and co-pilot, with one simple job: land the plane. But there is a problem – you aren't allowed to talk to each other.

The way *Sky Team* (Le Scorpion Masqué) works is that both players secretly roll a set of dice, then each uses the dice to take turns at various crucial tasks, such as steering the plane, setting its speed or operating the radio. At the same time, you have to use the dice as signals to the other player, which you desperately hope they will understand.

Take steering, which requires both players to put down one of their dice, with the difference between the values determining whether the plane banks left or right, or stays straight. Bank too far and the plane will crash, so you need to stay fairly close to the value placed by your teammate. If one player's first action is to put down a 1 on steering, that could be an attempt to communicate that all their other dice have higher values.

Of course, such attempts at communication can go wrong, and there is a lot of fun between rounds laughing as you fly wildly off course due to a misinterpreted signal. Bringing everything together to land the plane requires strong teamwork and a bit of luck, which makes for a nail-biting finish each time. ▮


Dimmer wheel allows you to precisely adjust the light output.
Standby switch and ergonomic handle helps you direct light beam precisely where you need it.
Light engine simulated high definition natural light. Guaranteed for 5 years.
Beam angle adjustment wheel intuitive beam adjustment offers beam personalisation.

Miss the comfort of reading in natural light?

Our HD Light brings daylight indoors. It uses Daylight Wavelength Technology™ to mimic natural light for greater reading comfort.

Offering crystal clear clarity and incredible colour rendition, a Serious Light is perfect for anyone who struggles to read small print for any length of time or who needs to see fine detail.

> First and only light to make a real difference.
>
> **Mr White | Warwickshire**

It will transform your visual experience.

Using Daylight Wavelength Technology™, inside every Serious Light are the latest special purpose purple LEDs, patented phosphors and bespoke electronics. The end result is a powerful light beam that closely matches natural daylight, something our eyes find most comfortable to read and work by.

When combined with the ability to adjust the beam width, dimming facility and fully flexible arm, a Serious Light enables you to enjoy reading again in complete comfort and see colours like never before.

Order by 17th December for guaranteed Christmas delivery*

Models shown:
HD Floor & Table

HD Floor Light Was ~~£399.99~~
Now £299.99

HD Table Light Was ~~£349.99~~
Now £249.99

Plus FREE Delivery worth £12.95

Klarna. available at checkout

SAVE £100 when buying any HD Light.

Quote offer code 8924 at checkout or when calling. While stocks last.

feefo ★★★★★ 4.9/5 (9,581 Reviews)
2023 Trusted Platinum Merchant

For Advice. For a Brochure. To Order:
0800 085 1088
seriousreaders.com/8924

Serious Readers
Serious about light™

*UK mainland

The truth about vaping

We finally have enough data to get a grip on the potential health consequences of this increasingly popular addiction, says **Graham Lawton**

AS THE old joke goes, when I read about the dangers of smoking, I gave up reading. If you are a vaper, you might feel like you want stop reading now. Don't: you need to know this.

I am a vaper. Like many others, I used to smoke and switched to vaping for health reasons. I plan to quit completely, but I haven't managed it yet. I am sure vaping is better for me than smoking, but I am also sure it is worse than not vaping. I cough in the morning and feel massively addicted to the nicotine. I don't even really know what I am inhaling. I worry that it will be hard to quit, that I am causing long-term damage to my body and that by vaping, I am susceptible to slipping back down the slope to cigarettes. I also have the same worries for the teenagers I see coming out of school and immediately enveloping themselves in sweet-smelling clouds.

As vaping has increased throughout the Western world, these fears have been repeated often. Part of last month's King's Speech in the UK focused on new legislation aiming to create a smoke-free generation in part by cracking down on youth vaping. Worldwide, there have been calls for tougher regulation and more investigation into vaping's health effects as increasing numbers of children admit to taking up the habit.

But there hasn't been a huge amount to say on whether fears over health effects are well-founded – until recently. Now, vaping has finally been around for long enough for answers to start emerging from the fog.

Modern e-cigarettes first went on sale in China in 2004. They entered the UK, US and other Western markets soon afterwards and have grown in popularity ever since. England now has about 4.5 million regular or occasional vapers – 7.5 per cent of the population. The US has a similar percentage. Vaping among teens and young adults has rocketed, peaking at 27.5 per cent in high school students in 2019 in the US, according to the US Food and Drug Administration National Youth Tobacco Survey. In the UK, the proportion of children aged between 11 and 17 experimenting with vaping grew by 50 per cent in the past year. This is all despite it being an offence to sell e-cigarettes to people under 18 in the UK and under 21 in the US.

Harmful ingredients

Vapes vary in design, but they all have the same basic features: a tank for the "e-liquid", a heating element to vaporise the liquid and a mouthpiece to inhale the resulting aerosol. Despite the name, vapes don't produce vapour, but rather a suspension of particles and droplets in a gas. For that reason, many health bodies prefer to call them electronic nicotine delivery systems, or ENDS. E-liquids typically contain nicotine and flavourings, as well as a solvent to dissolve them and convey them into the lungs. The most common solvents are propylene glycol and glycerin.

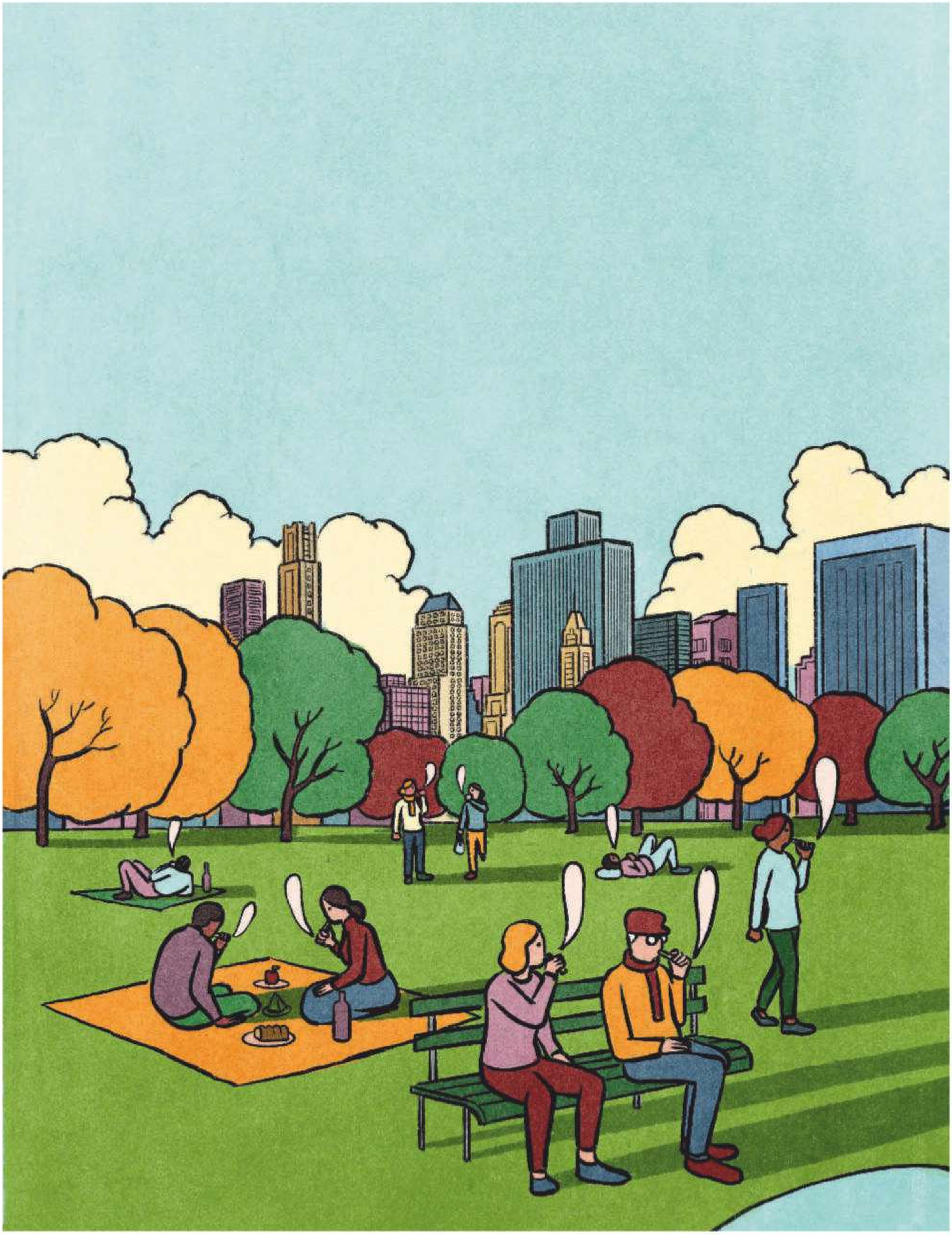
The short-term health impacts of vaping – and some potential long-term consequences – are now quite well-known. What has become clear is that they aren't all sweetness and light. Let's start with the e-liquid. All three of its standard ingredients can do immediate harm. Nicotine is addictive and overstimulates the sympathetic nervous system, causing the heart to beat harder and faster and blood pressure to rise, according to the American Heart Association (AHA), which published a scientific statement on ENDS in July. As yet, there is no evidence of this leading directly to heart attacks or other cardiovascular problems, but chronic overstimulation of the heart is known to be a risk factor for cardiac failure.

The solvents, meanwhile, can irritate and inflame the airways. Propylene glycol and glycerin are both generally recognised as safe by the FDA, by which it means they are non-toxic. However, manufacturers of the chemicals recommend that inhalation be avoided. Short-term exposure can lead to coughing, a sore throat and decreased lung function. Perhaps that is where my morning cough has come from. In studies on the effects of theatrical smoke, long-term exposure to propylene glycol is associated with wheeziness and chest tightening.

Some flavourings found in vapes also ring alarm bells for the AHA. The buttery compounds diacetyl and acetylpropionyl are known industrial hazards. Some of the other common flavours – menthol, coffee, strawberry, chocolate, cinnamon, sweet tobacco, caramel and vanilla – contain compounds that produce inflammatory responses in cultured cells. Sweeteners including sucrose and glucose, meanwhile, are converted by heat into compounds called reactive aldehydes, which are believed to be a leading cause of heart and lung disease in smokers.

Vapes also chuck out some unintentional byproducts, including heavy metals released from the heating element. Some elements contain a nickel-chromium alloy: rats exposed to nicotine-free aerosols produced using these elements developed wheezing and laboured breathing, while stainless steel elements

›



KLAUS KREMMERZ

didn't have the same effect. Studies of people exposed to nickel and chromium compounds through their occupation show an association with increased risk of lung cancer, and nickel is one of the few carcinogens to be found in higher amounts in some vapes than in tobacco smoke. There is also evidence that the older an element or disposable vape, the more heavy metal pollution it spews out. The 101st-to-150th puffs on a disposable produce about 60 times as much as the first 50.

Vape aerosol also delivers some of the nasties found in tobacco smoke: carbon monoxide, tobacco-specific nitrosamines and volatile organic compounds (VOCs), such as formaldehyde and acrolein. But where data exists, it consistently shows much lower levels of exposure from vaping than from smoking, according to a 2022 review by Public Health England (PHE). I blew some vape aerosol into my indoor air quality monitor and was pleasantly reassured by the fact that it failed to trigger the VOC alarm, which occurs when they reach a harmful concentration.

> "The buttery and cinnamon flavours are a cause for concern"

When it comes to identifying the relationship between vaping in general and cancer, there are some red flags. Some animal and cell culture studies suggest that vaping may produce the kinds of DNA damage, inflammation and other biological alarm bells that are known to precede a tumour. One study exposed mice to 54 weeks of vaping aerosol and found that they developed lung and bladder cancer much more often than their non-vaping counterparts.

However, whether these effects in animal models correspond with a risk of disease in humans isn't yet clear (see "Does vaping wreck your lungs?", page 35). "The precise long-term effects of vaping nicotine will not be fully known for decades," says Wayne Hall at the University of Queensland in Brisbane. In a recent statement, the AHA points out that it took decades to establish the link between smoking and lung cancer, but vaping has only been widely practised for 10 years.

Nonetheless, the review by PHE answers some other important questions. It found little evidence of toxic substances in the bodies of vapers, with significantly lower levels than in smokers, and often the same or only slightly higher levels than in people who don't smoke or vape. It also looked at biomarkers associated with cancer, respiratory and cardiovascular conditions and found the same pattern. Nor was there evidence of a risk from second-hand vape.

PHE did flag up the buttery flavourings and cinnamaldehyde (which gives a cinnamon flavour) as potentially concerning, but absolved the solvents. Overall, the review concluded, even though vaping isn't risk-free, it "poses a small fraction of the risks of smoking" in the short and medium term. This is in keeping with its earlier review, from

How to vape (more) safely

It is best not to vape at all, but if you must, here is how to minimise the risks:

Heating element: Avoid elements containing heavy metals such as nickel, chromium, copper and lead, as the toxic metals find their way into the aerosol and have previously been associated with an increased risk of lung cancer (see main story). Stainless steel elements appear to be safer. If you can't find these, change the element at least once a week, as the metal contamination gets worse with age. It can be hard to find out what the coils are made of because the packaging rarely specifies, but a bit of web sleuthing can pay off. I discovered that the coils I use are made of Kanthal, an alloy of iron, aluminium and (gulp) chromium. I will be searching for "stainless steel coils" instead.

Flavours: Early evidence suggests that flavourings can be hazardous, but some are more hazardous than others. A review by Public Health England flagged up buttery flavourings and the cinnamon flavouring cinnamaldehyde as being of special concern. The main buttery flavours, diacetyl and acetylpropionyl, are banned as e-liquid ingredients in the UK, but may be sneaked in by unscrupulous manufacturers, according to scientific consultancy group Broughton. E-liquid packaging rarely discloses the chemical names of its flavourings, so it might be wise to avoid buttery and cinnamon ones.

Solvents: The two most common solvents, propylene glycol and glycerin, appear to be equally safe (or dangerous, depending on your perspective).

Air: Open device vents to reduce the concentration of flavourings, nicotine and contaminants in the aerosol.

Vaping appears to be a successful way to help people stop smoking

DAVID PAUL MORRIS/BLOOMBERG VIA GETTY IMAGES

SUPERSIZER/GETTY IMAGES

There is no evidence of health risks from second-hand vape

Does vaping wreck your lungs?

Between August 2019 and February 2020, 2807 people in the US were hospitalised with a condition characterised by lung injuries and pneumonia. Of these, 68 died. Most who fell ill were vapers, and the illness was dubbed EVALI, which stands for e-cigarette or vaping product use-associated lung injury. The outbreak sparked fears of an epidemic of lung disease and a hearing in US Congress about the dangers of vaping.

The culprit turned out to be backstreet cannabis oils cut with the solvent vitamin E acetate, which is converted to the potent lung toxicant ketene when heated. The acetate isn't an approved ingredient of vape liquids. "There is no evidence that vaping nicotine causes EVALI," says Wayne Hall at the University of Queensland in Australia. There are, however, some red flags that vaping may lead to unhealthy lungs in other ways (see main story).

2015, in which it concluded that e-cigarettes are around 95 per cent less harmful than smoking.

That chimes with my experience. I have smoked. I have vaped. I have mixed and matched, and I have abstained altogether. Quitting both is obviously preferable, and I will get there one day, but smoking feels at least 20 times worse for my health. And it stinks.

Indeed, I have much to thank my vape for. I have successfully used it to wean myself off smoking, as have many others. According to PHE, data from smoking cessation services in England shows that vaping is now a key weapon in the smoke-free arsenal. People who go cold turkey have a roughly 50 per cent success rate over a four-week period from their date of quitting. Switching to a vape increases that to just over 60 per cent. Vaping plus a prescription drug (nicotine replacement therapy, or the now-unavailable bupropion or varenicline, which were withdrawn from the market after reports of contamination with toxins) was even more successful.

Longer-term studies also show the relative success of vaping as a smoking-cessation tool. According to a recent review by the Cochrane Collaboration, an independent medical evidence review body, up to 14 per cent of vapers stayed smoke-free after six months, compared with 6 per cent of people using nicotine replacement therapy and 4 per cent of those receiving behavioural therapy or nothing.

But does it also cut the other way? Since vaping became popular among young people, there have been persistent fears that it acts as a gateway drug, luring them into smoking, perhaps through getting them hooked on nicotine or habituated to handling and inhaling from a cigarette-like object.

In 2017, a team led by Samir Soneji, now at Duke University in Durham, North Carolina, published an influential study on this pressing question. The researchers analysed the existing data on whether teenagers and young adults who try vaping are more likely to subsequently take up smoking. The answer was a resounding yes. Around 23 per cent of those who dabbled in vapes later took up smoking, while only 7 per cent of non-vapers did. The study accounted for other known risk factors for starting smoking – having parents, siblings or friends who smoke, and scoring high for traits like sensation seeking and risk taking – leading Soneji and his team to conclude that there is a "causal correlation" between vaping and smoking.

> "The rise in youth vaping accompanies a decline in youth smoking"

This appeared to be confirmation of the gateway hypothesis. But in subsequent studies that controlled for more risk factors, including use of alcohol and marijuana, the correlation melted away. "Most of the association between vaping and subsequent smoking has disappeared," says Hall.

In any case, says Hall, if the gateway hypothesis is true, then as youth vaping rises, so should youth smoking. But the opposite has happened: the rise of youth vaping has been accompanied by a decline in youth smoking in the US, UK and New Zealand. In the US, in 2011, 16 per cent of 15 to 18-year-olds smoked, while only 2 per cent vaped. Today, those figures have effectively reversed. "At most, [there is] a small gateway effect that is outweighed by the much larger number moving from smoking to vaping," says Hall.

Still, though, the controversy goes on. "There isn't yet a consensus as to whether the use or availability of e-cigarettes causes young people to smoke who wouldn't have otherwise," says Jamie Hartmann-Boyce at the University of Massachusetts Amherst. "Though young people who vape are more likely to go on to smoke than their non-smoking peers, it's not clear if this is because vaping causes them to smoke or if something about people who vape also makes them more likely to smoke."

But teen gateway or not, vaping as an adult instead of smoking appears to be doing some good in terms of cutting smoking rates. In the US, the adult smoking rate since the introduction of vapes has fallen from 21 per cent to 11 per cent. In the UK, about 13 per cent of adults smoke, half the number that did in 2005. Vapes aren't the only factor, but, according to Hall, "the evidence suggests that vaping is displacing smoking at a population level". In a perfect world, nobody would smoke anything. Vaping isn't the ideal solution, clearly, but it may be an imperfect way of moving us in the right direction. ∎

Graham Lawton is a features writer at *New Scientist*

ANCIENT Egypt, the Roman Empire, the Maya, China's Qing dynasty – these civilisations all shone brightly in their time. Yet, in every case, the glory days were followed by collapse. This seems to be the inevitable trajectory of any culture. What's more, it looks like Western civilisation is experiencing this fate right now. Signs of crisis are obvious, from rising economic inequality and political polarisation to violent conflict and ecological disasters. Many see this as a global "polycrisis" that poses a severe, possibly existential, threat to contemporary societies.

I predicted this would happen. More than two decades ago, I began applying the mathematics of complex systems to history in an attempt to uncover underlying patterns. Using this approach, I discovered that violent political instability follows two cycles, one peaking every 50 years or so, superimposed over another that does so every two or three centuries. Applying this to the US and western Europe, I was shocked to discover that these societies were well advanced on the road to crisis. In 2010, in *Nature*, I forecast that crisis would escalate and peak during the 2020s. A decade later, the evidence supported that prediction.

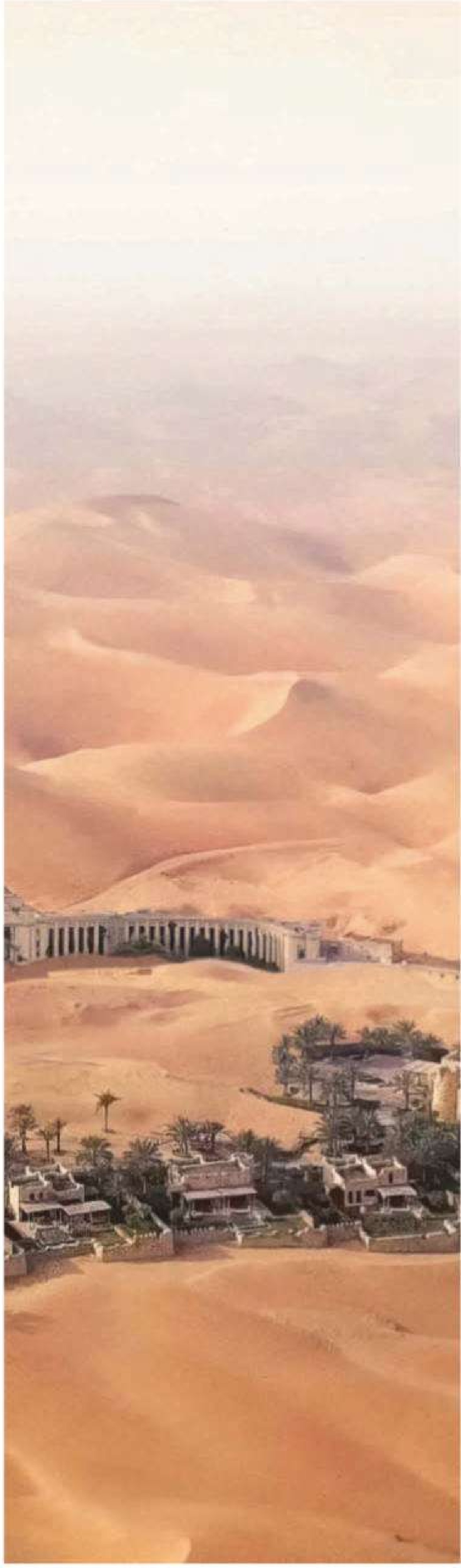
You might have come across some of these ideas recently, following the publication of my book *End Times*. Perhaps unsurprisingly, reviewers used words like "collapse", "revolution" or even "doom" to describe my work. So, it may surprise you to learn that I don't believe collapse is inevitable. In fact, my latest research reveals something fascinating and encouraging: human societies have evolved to become less prone to collapse. Better yet, this insight could help us weather the current crisis.

For over three decades, my colleagues and I have been gathering data on past societies as they slid into crisis and then emerged from it. This is painstaking work because we need information about dozens of quantifiable variables that describe the key characteristics of social systems and capture their dynamics. Where direct indicators aren't available – the further you go back into the past, the more common this is – we must find indirect indicators to act as proxies. Currently, we have data on nearly 200 cases of crisis covering the past 5000 years, and we have used this to compile a massive historical database called CrisisDB. With this, we can start to look for patterns.

One surprise is how few variables are needed to determine whether a society is sliding into crisis. Public debt, loss of state legitimacy and geopolitical and geo-economic pressures from abroad all play a role. But the

HEADING FOR A FALL?

Reports that Western civilisation is about to collapse are premature, says complexity scientist **Peter Turchin**



FABIEN BARRAU

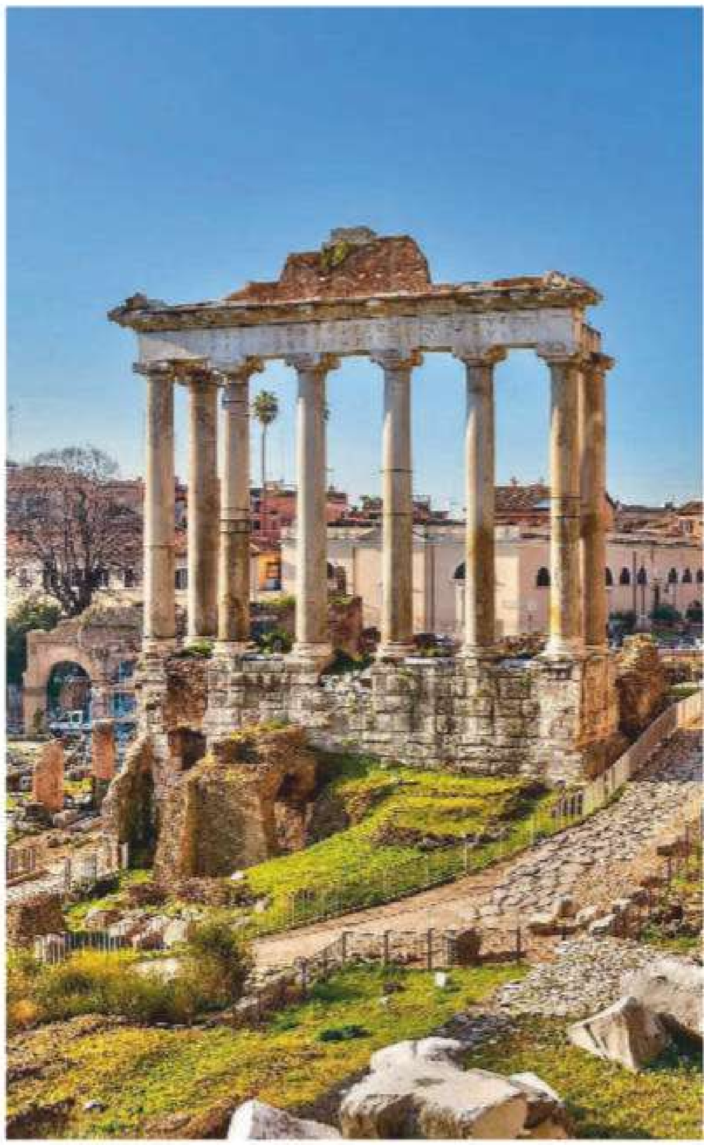
two main indicators of impending crisis are "popular immiseration" – meaning stagnating or even declining well-being of the majority of the population – and "elite overproduction", which refers to a society producing massively more elite wannabes than the number of power positions available to them. These two indicators are linked because, to effectively challenge the status quo, popular discontent (feeding off immiseration) needs to be channelled and organised by dissident elites (those frustrated in their quest for influence and wealth).

Although the lead-up to crisis is quite stereotypical, our analysis reveals that there is no such thing as a typical collapse. CrisisDB allowed us to identify a total of 13 consequences of collapse, and our analysis shows that there is enormous variability in how crises play out (see graphic, page 38). The most common ways societies emerge from their "end times" are through bloody civil war or violent revolution. Other possible outcomes include severe demographic consequences, even resulting in a loss of the majority of a population, rulers being deposed or killed, and governing elites being overthrown by a social revolution – or sometimes exterminated. Crisis can also lead to territorial fragmentation, the destruction or abandonment of the capital, or conquest by external enemies. Utter collapse (when a society crumbles along many dimensions) is quite rare. Instead, a few dimensions tend to dominate. And in some cases, leaders and populations manage to pull together and navigate social upheaval in a non-violent way. Collapse isn't inevitable.

Let's make this result more concrete by considering a wave of social instability that swept the globe two centuries ago. Although crises are mainly driven by internal factors, no country lives in complete isolation, so wider influences – geopolitical, economic and cultural – tend to bring crises in different states into imperfect synchrony. In my previous work, I have found that such "ages of discord" recur approximately every two centuries. Today, we are living in our own age of discord. The previous one, the age of revolutions, peaked during the middle of the 19th century (although aftershocks lasted until the early 1900s). It included the revolutions of 1848, which swept through Europe from France to Germany, Austria, Italy and a host of smaller nations. Also, starting in 1850 and peaking during the 1860s, there was turmoil in China, Russia and the US. Essentially, all large nations in the world were affected by this wave of instability. Nevertheless,

›

“Societies became more resilient because they became more complex”


SERGEY BORISOV/ALAMY

the severity of outcomes differed wildly.

The worst episode was the Taiping Rebellion, which occurred in Qing China between 1850 and 1864. Some 20 to 30 million people died, making it the bloodiest civil war in human history. Likewise, the American civil war that ran from 1860 to 1865 is the bloodiest war in US history, killing over 600,000 people. On the other hand, the British Empire, while experiencing much unrest during the Chartist era of 1838 to 1857, managed to avoid a violent revolution. Instead, the governing elites cooperated and adopted a set of reforms that defused the crisis, such as allowing workers to organise and extending the right to vote. Another large empire, Russia, also avoided collapse. It slid into crisis during the 1850s, yet despite a humiliating defeat in the Crimean war, mounting peasant unrest and a bombing campaign by anarchists, things ended in a relatively non-violent way, with the government adopting a set of reforms, including the abolition of serfdom.

In the current age of discord, this historical evidence is heartening. But our latest analysis of CrisisDB sends a message that is even more positive. When my colleagues and I looked at how crises played out in different societies throughout the 5000 years encompassed by the database, we found that early states were much more fragile than those that followed. There is a strong empirical pattern: as we get closer to today, social and political breakdowns resulting from crisis become less severe.

To see this in quantitative terms, let’s focus on one dimension of collapse, population decline. This is warranted because the size of a society is perhaps its most fundamental characteristic, and because population collapses reflect untold human misery as people die due to violence, epidemics and famines, or become refugees. Furthermore, famous examples of collapse in past societies typically involved drastic decreases in the population. The end of the Maya civilisation is a good example – although it was only with the advent of modern technology, such as lidar, that archaeologists discovered that the jungles around abandoned Maya centres were once packed with houses, fields and roads.

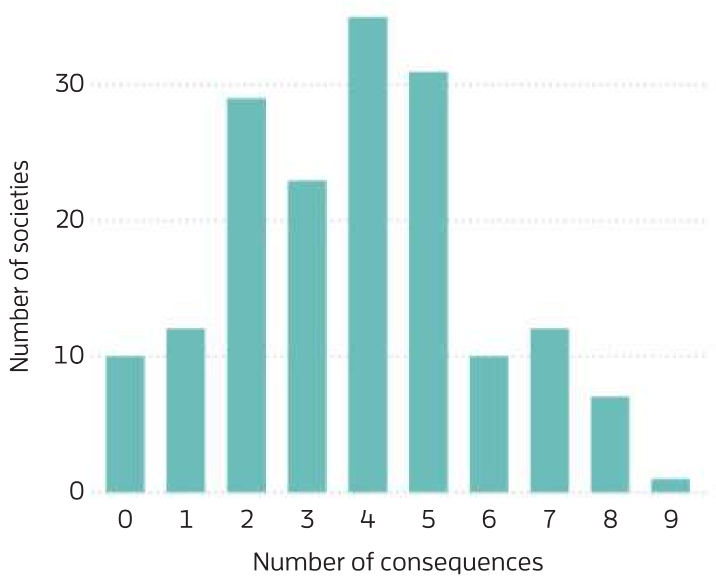
What do we see when we measure the severity of past crises by the extent of population decline? First, take the Taiping Rebellion again. It reduced the population of China by 13 per cent – from 412 million in 1850 to 358 million in 1870. Despite the scale of this loss, it pales into insignificance when compared with the Han dynasty’s collapse in the year AD 220. At its peak, the dynasty’s population was about 60 million. After the collapse, it was less than 20 million. End times of subsequent dynasties that ruled China – the Tang, Song and Ming – also involved substantial population loss, but the trend was for the severity of these declines to diminish with time. Or take what is now Germany. As mentioned earlier, it was convulsed by revolution in 1848. But this wave of instability had no serious demographic consequences. Contrast that with the preceding age of discord, which occurred in the 17th century. Starting in 1618, the thirty years’ war raged in Europe, killing millions and leaving some regions of Germany with just 50 per cent of their former population.

These examples illustrate the overall trend during human history. But our analysis reveals more. The reason human societies became more resilient is that they became more complex – albeit, in a certain way. This sounds surprising: it is a common trope in archaeology that complex societies are highly prone to collapse. Indeed, in his influential book *The Collapse of Complex Societies* Joseph Tainter at Utah State University argues that it is precisely the accumulation of complexity that undermines stability. But that isn’t what our analysis reveals.

To understand this, we need to distinguish between two dimensions of complexity. The

What becomes of a society in crisis

Analysis of around 200 societies over the past 5000 years points to 13 major consequences of crisis (see key). However, the number of consequences experienced by societies varies hugely: some manage to weather a crisis with few or no consequences, whereas others experience many consequences and total collapse



1. Population decline
2. Population collapse (loss of >50%)
3. Epidemic
4. Downward mobility of elites
5. Extermination of elites
6. Popular uprising
7. Civil war
8. Long civil war (> 100 years)
9. Territorial fragmentation
10. Loss or destruction of capital
11. External conquest
12. Ruler deposed
13. Ruler assassinated or executed

The Roman Empire eventually collapsed but modern states are less fragile

How to avert a crisis

Western civilisation is in trouble, but an analysis of history reveals how we can avoid collapse (see main story). The trick is to bolster the right kind of social complexity – in particular, institutions and policies that boost the well-being of the majority of people and reduce conflict between elites:

1. **Progressive taxation reduces the creation of too many wealthy elites and the economic impoverishment of the rest**
2. **A universal right to vote and the election of public officials constrain arbitrary and selfish behaviour by rulers**
3. **Labour-protecting institutions, such as unions, and a minimum wage decrease economic inequality**
4. **A welfare state equitably promotes the well-being of all citizens**
5. **International cooperation through the United Nations and its agencies, such as the Intergovernmental Panel on Climate Change, helps address global challenges**

first is scale. Most simply, it is population size, the number of people governed by a state or empire. But there are other aspects of scale, including a state's territory, or how many people live in the capital and other cities. As the scale of a society increases, it becomes harder to govern. Regions away from the capital are more prone to separatism and secession. Tensions arise between different ethnic groups within large multiethnic empires. Because their scale has tended to increase since states emerged some 5000 years ago, this trend should have resulted in them becoming more fragile.

Useful complexity

But a second dimension of complexity provides a countervailing trend. States didn't just increase in scale, they also evolved institutional complexity. As a result of interstate competition and conflict, they acquired more sophisticated systems of information processing, economic exchange and governance. State bureaucracies became more effective and so did the constraints on rulers and elites. Like any form of evolution, this entailed survival of the fittest. Put simply, states that failed to acquire this sort of complexity collapsed and their territories and populations were taken over by more capable rivals. Thus, what makes societies better able to resist internal and external shocks is "useful complexity" – essentially, the accumulation of social technologies that make them better organised and more internally cohesive and functional.

Taking this idea further, my team recently carried out a major new analysis of Neolithic societies as they spread from Asia through Europe between 9000 and 5000 years ago. These first farmers of Europe lived in societies that were simply organised. Essentially, each village was its own independent polity. There was no writing, no bureaucrats and, apparently, no hereditary rulers (those became prominent during the subsequent Bronze Age). Yet, these pre-state societies weren't immune to demographic collapse. Wherever we have detailed information on population dynamics, we observe that peaks were typically followed by declines in which more than half of the population disappeared and the whole region was sometimes abandoned.

This is a different kind of collapse than the multidimensional process we identified in complex human societies, organised as states. Furthermore, the causes of these drastic population declines are debated: some researchers invoke climatic change, others blame soil exhaustion, yet others look for evidence of an epidemic. Our analysis suggests violent conflict was a major culprit. Whatever the causes, accumulating evidence shows that demographic collapses weren't rare in prehistory. As we acquire quantitative data on more regions, it is beginning to look like such drastic population declines are the rule rather than the exception.

The implications of this study, taken together with the results of our analysis of CrisisDB, are startling. The long arc of human cultural evolution over the past 10,000 years has resulted in increasingly larger-scale societies. Such societies attempted to suppress internal violence, with varying degrees of success. Initially, they were quite fragile and readily descended into civil wars that tore them apart. But they gradually evolved more and better institutions that increased their resilience against internal and external shocks. Collapse became less likely.

I believe we can exploit this finding to help us achieve a better outcome in the crisis that is currently rocking Western civilisation. Modern societies already possess a lot of "useful complexity", but we need to bolster the practices and institutions we know will make us most resilient to collapse (see "How to avert a crisis", left). Also, societies are more interconnected and the problems we face are more global than ever in human history. We must reflect this in the social complexity we embrace if we are to rise to such challenges as climate change, war and inequality.

Time is running out, so we can't simply wait for cultural evolution to solve this for us. What I have learned from detailed analysis of past success stories – ones where states avoided a descent into civil war and resolved their crises through the right mix of policies and reforms – is that, ultimately, it takes action by key individuals. To avoid collapse, elites must be made to care about the common good. And that requires two things: pressure from grassroots social movements and selfless individuals to lead them. ▮

Peter Turchin is project leader at the Complexity Science Hub Vienna in Austria. His new book, *End Times*, is out now

KLAWE RZECZY

‘We need to bring AI into contact with the real world’

Artificial intelligence may never reach its full potential unless it can interact with the physical environment. That means we need to give it a body, roboticist **Josh Bongard** tells Edd Gent

WHO’S in charge, your brain or your body? The answer may seem obvious, but there is plenty of evidence to suggest that our physiology has dramatically affected the way we think. This idea of embodied cognition could hold important lessons for those trying to build genuinely intelligent machines – artificial intelligences that learn and think and can generalise their knowledge to all manner of tasks, like humans.

Josh Bongard, a roboticist at the University of Vermont, is among those who insist AIs will only fulfil their promise if they can directly experience and interact with the physical world. That is a far cry from AIs like ChatGPT, whose only interactions with the world come via the abstract medium of language. But the field of embodied AI is pushing for the convergence of artificial intelligence and robotics, and Bongard is at its forefront.

He reckons we need to rethink our approach to both disciplines. Simply integrating an AI chatbot with a robotic arm, as Google has done with its PaLM-E system (pictured, page 43), may not be enough. Instead, Bongard focuses on “evolutionary robotics”, which leverages the principles of natural selection to rapidly iterate through robot designs, many of them made of soft materials. He is also part of a team using living cells to form simple biological robots, known as xenobots, that not only perform basic tasks, but can interact with and respond to their environment too.

Here, Bongard tells *New Scientist* how this work is suggesting entirely new ways to think about embodied cognition, and what counts as a robot, which could transform our approach to building intelligent machines.

Edd Gent: How does the body influence the way we think and learn?

Josh Bongard: There’s little in the way humans understand the world that isn’t directly or indirectly influenced by our physiology. We use our bodies to push against the world and we use our sense organs to observe how the world pushes back. This feedback loop is how we learn about the world. It also means that different bodies generate different action-reaction results and thus learn about the world differently. For example, a big, land-based animal should see high cliffs and water as dangerous. But flying animals may see a cliff as a good launching point, and insects see water as something that can be walked across.

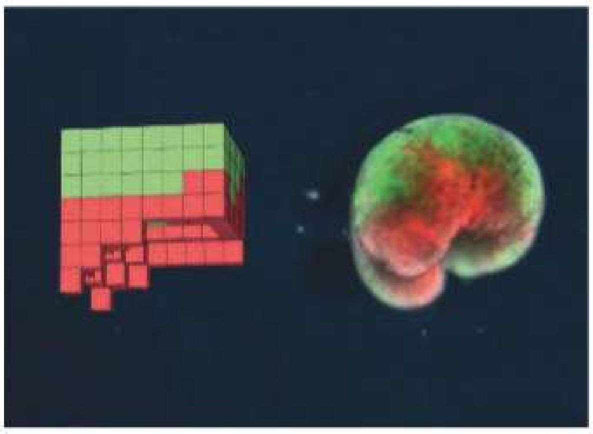
Some of the simplest clues to that connection between the body and the way we think are hidden in language. Since humans have forward-facing eyes, when we walk, we are looking at objects and situations that are about to become our future. This means that humans › tend to "look ahead" to events weeks or years in the future, or "look back" with regret or nostalgia on past events. Even in abstract ways of thinking like mathematics, we talk about manipulating an equation. The root of the word manipulation is about hands, and a lot of mathematicians report visualising themselves pulling apart and recombining mathematical concepts with their hands.

What lessons does that hold for people trying to create artificial intelligence?
That connection between the body and the way we think is something that is not always obvious to us, and something that we haven't really built into our machines. In my opinion, that is one of the missing ingredients from all these very powerful, yet surprisingly flawed, intelligent technologies: the lack of a body and the lack of understanding of the connection between the real world and the world of intelligence, abstraction, reasoning and cognition.

You can sense that some of these AIs have fundamental flaws. There are gaps in their knowledge and understanding about the real world. Those of us that work in embodied AI, we point to the fact that ChatGPT has never had the ability to push against the physical or social worlds and see how they push back.

> "Evolutionary robotics builds new kinds of robot bodies and brains"

Also, current AI is good at generating things such as images and videos and responses to questions, but it can't make anything physical. It has no access to the real world. It doesn't know what works and what doesn't work. This is an important aspect of intelligence. It's relatively easy to dream up new ideas, but the value of intelligence in humans is that you can demonstrate that they work in the real world.



DOUGLAS BLACKISTON/SAM KRIEGMAN

AI designs for a walking soft robot (left) and a living robot made of frog cells (above)

Is it enough to hook up a large language model (LLM), the kind of AI system behind the likes of ChatGPT, to a robotic body, as Google has done with PaLM-E?
I think nobody knows at the moment. There is this growing awareness that we need to embody LLMs or we need to bring AI into contact with the real world somehow. PaLM-E is one way to do it, which is to basically make a huge brain in a vat and then hook it up to a complex physical machine [in this case an articulated arm with a kind of grasping claw capable of picking things up]. Whether or not that's going to work in the long run is anyone's guess, but it's definitely not the way Mother Nature does it.

She starts simple. Most animals begin as single cells, which then divide and become specialised such that the animal itself grows gradually more complicated, both on the brain side and the body side. And there are good reasons for that. When we're teaching a child to ride a bike, we don't put them on a full-sized bike to start with. We put training wheels on the bike, we make the task easier for the learner. Your own development is your training wheels. Making very sophisticated bodies and brains and then mashing them together and crossing your fingers, I don't think that's going to be a recipe for long-term success.

What kind of bodies should we give robots?
This is part of the fun of this next stage of creating intelligent machines. If the body is important for acting intelligently and safely in the real world, what body is the right body for a given task? In the very early years of aviation, most of the ideas were: "Should we make a large thing that flaps its wings or should we make a small thing that flaps its wings?". Of course, the Wright brothers' answer was neither. Nature has been incredibly creative in all the physical forms she's discovered, but we don't necessarily have to stick with what she came up with.

I work in this space called evolutionary robotics, where we ask AI to design not just the brain of the robot, but the physical structure of the robot – the right brain-body combination for the job at hand. Most robotics folks are building the products of evolution, but in evolutionary robotics we're trying to build the process of evolution. And that process produces new kinds of robot bodies and brains unlike anything we've seen in nature before.

Evolution takes a long time, so you rely on simulations to accelerate it. That works fine for simple robots and simple environments, but is it feasible for more complex problems?
We don't necessarily need to do evolution the way it happens in the real world. Biological evolution is blind: it makes progress through random mutations. But we published a paper in October showing that you can reduce the error in the trial and error. You can create an AI that watches its robot designs in simulation

and when the design doesn't do what we want, the AI can backtrack into the body of the robot and identify exactly where things went wrong.

We showed that this can speed up robot design in simulation from two weeks on a supercomputer to 30 seconds on a laptop. The resulting algorithm is still designing relatively simple robots, the sort that kind of shuffle around a little bit. But if we can design simple robots in 30 seconds on a laptop, now we can start to think about designing more complex and capable robots using this process.

ROBOTICS AT GOOGLE/TU BERLIN

Google's PaLM-E robot combines AI with vision and a dextrous hand

What might those robots look like?

A lot of my colleagues work in this relatively new field known as soft robotics. So, instead of making robots from metal and ceramics, why don't we make them from rubber and silicone and soft things? Why don't we build them with hollow chambers inside, where we can inflate those bladders to increase the size of the robot?

Soft robotics is a really promising real-world technology that allows us to make robots that are safer, just by the simple fact that they're soft. But being soft also means you can deform and change shape and change size. You can extrude arms and legs and fingers and tools, and then retract them when they're no longer needed. So, I think there are a lot of advances that are occurring in material science that allow us to make robots from more exotic materials, mixtures of soft and rigid components.

In recent years, you've also been working on building robots out of living materials. How is that work related to embodied AI and evolutionary robotics?

I've been working with Michael Levin at Tufts University in Massachusetts, who has shown that animal body plans are more open to suggestion than we previously thought. What I mean by that is that you can surgically rearrange tissues in an animal embryo and, in many cases, it will grow into an adult organism that looks and acts very differently from the wild type. For example, Mike showed that you can surgically rearrange the eyes in a frog embryo so that it grows into an adult frog where the eyes are on the back.

About six years ago, I teamed up with the Levin lab to ask: "If a human biologist can come up with a way to rearrange living tissue to produce a new kind of organism, could we get an AI to dream one up?". We asked the AI to put frog skin and heart cells together in a particular pattern that would produce something that walks along the bottom of a Petri dish. The heart tissue increases and decreases in volume, so it can act like little pistons or little motors. We set the AI to work for about two weeks on a supercomputer and it tried out millions of different arrangements.

At the end of that two-week process, it sent us back a short video of a virtual frog bot. We passed that video to a microsurgeon in Mike's lab, who spent a few hours painstakingly putting cells where the AI said they should go. Then he let go of his little creature and this xenobot walked along the bottom of the Petri dish.

That's an impressive feat, but are robots built out of biological materials anything more than a research curiosity?

This is still very basic science. That being said, I'd be surprised if AI-designed organisms do not eventually find applications in certain areas. They are very small. There are a lot of use cases in which very small robots that go, look, remember and come back would be very useful, but it's hard to make very small machines out of traditional components. They're also biocompatible and biodegradable, so they would be a very eco-friendly technology.

What can they tell us about the role morphology plays in intelligence?

They're already telling us many things about the nature of embodiment and intelligence. They show some of the rudiments of intelligence: they seem interested in certain things in their environment and they shy away from other things. But they're just frog skin and heart cells, there is no brain. The individual cells have never been in this particular arrangement before, but somehow they figure out what to do. They communicate with each other electrically, chemically, mechanically, they push and pull on each other. And they seem to work together to do what the AI wants them to do.

The intelligence resides in the cells. This is a machine made up of intelligent machines. And so it's suggesting completely new ways to make intelligent technology. People often ask us, "How do you program these robots?" and we kind of smile and say, "That's the whole point." There is no programming. There's no little biological computer inside these robots. There's no distinction between the controller of the machine and the machine itself.

So maybe we've been going about it wrong this whole time. It may be that what we typically refer to as the brain is a support structure, it's not the command-and-control centre. Mammalian brains are one of the most recent inventions Mother Nature came up with. Bodies have been around for a very long time, so it's possible that most of the intelligence resides in the body, and brains are just there to facilitate or enhance that latent intelligence. ∎

Edd Gent is a technology journalist based in Bangalore, India

Debunking gardening myths

Raking it in

When the leaves start falling, we can spend hours removing them from our lawns. We needn't bother, says **James Wong**

James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, in London, he shares his tiny flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

Debunking gardening myths appears monthly

Next week
The science of cooking

IT IS late autumn where I live in London – a time of year that sees millions of gardeners like me, across the northern hemisphere, donning their thickest jumpers and spending hours raking giant piles of leaves into plastic bags at the end of driveways. In the US alone, nearly 10 million tonnes of garden waste go to landfill every year. That is a phenomenal amount of effort, not just from an environmental perspective but frankly from that of our creaking backs, too. So wouldn't it be great if there was an alternative?

Strangely, despite it being one of the most deeply ingrained of gardening practices, this seasonal chore makes very little sense ecologically. In natural ecosystems, falling leaves help return minerals essential for healthy plant growth to the soil, and they add organic matter, which greatly improves soil structure. This makes forest soils some of the richest on Earth, as plants continually generate their own fertiliser. Removing leaves year after year breaks this beneficial cycle. So where does this illogical advice come from?

Well, it largely stems from the belief that thick blankets of fallen leaves can choke plants beneath them, especially shorter species like lawn grass, creating a light-excluding layer that shuts down essential photosynthesis. The surprising thing is, this received wisdom has only recently been scientifically scrutinised, with a range of studies all pointing to the exact opposite conclusion.

MAX BELCHANKO/SHUTTERSTOCK

According to researchers at the University of Wisconsin-Madison, if up to 20 per cent of your lawn is covered by fallen leaves, you might as well go back indoors and put your feet up. The fertility benefits of this light leaf coverage far outweigh the drawbacks – the leaves will quickly break down and help next year's lawn grow far better than if you had raked them.

Even a much denser coverage of up to 50 per cent still won't require raking. Instead, the new consensus is simply to run a lawnmower over your lawn, shredding the leaves into a fine confetti of smaller pieces. These will break down faster and scatter more evenly.

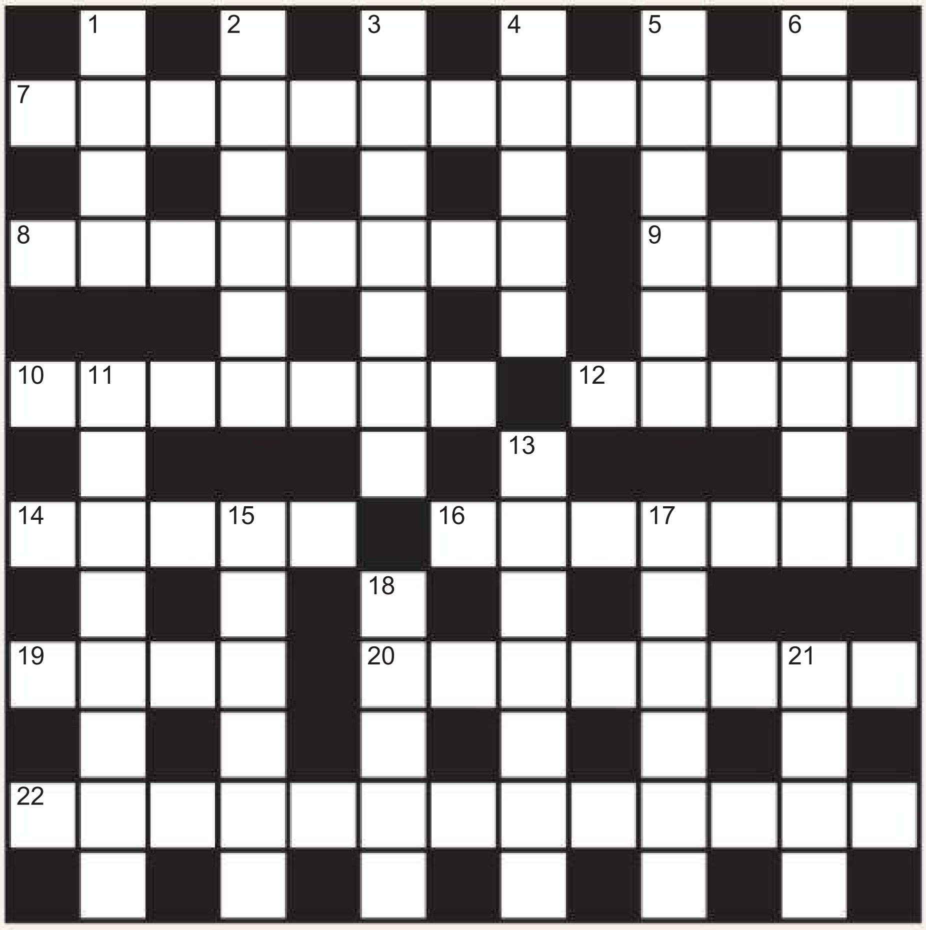
Only at over 50 per cent coverage do the Wisconsin researchers recommend raking, and even then they advise moving the leaves to adjoining borders under larger plants, not off site.

Other studies don't recommend raking at all, just a once-over with the mower, even for leaf carpets up to a whopping 45 centimetres deep! Save time, carbon and effort, and in exchange get a healthier lawn from free fertiliser you have grown yourself – that seems like a pretty good deal.

And for geeks (like me) wondering how many giant plastic bags could be saved by simply not binning this homegrown fertiliser every year? I weighed a bagful myself to do the (very rough) maths: in the US alone, approximately 700 million. ▮

These articles are posted each week at newscientist.com/maker

Cryptic crossword #124 *Set by Trurl*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

7 Spooner's advice on maintaining a meadow? Take a look, it's very depressing (4,2,3,4)
8 On radio, counts chess piece as lucky charm (8)
9 It may be put on at the Bolshoi – but not first, we hear (4)
10 It's back: paper by Trurl's poor boy in book (4,3)
12 Humeri mostly broken, resulting in discharge (5)
14/2 Down Song's second-rate, not even #1 in Italy this year, for starters (5,6)
16 Organ of British Library, associated with summer, perhaps (7)
19 Woods disheartened by row (4)
20 Measure *n* inaccurately and reveal login detail (8)
22 After bad delivery, go fishing near French city – it gives a broader perspective (4-5,4)

DOWN

1 Aztec almost entirely misrepresented in letter from Greece (4)
2 See 14 Across
3 Method I used to reconstruct skull bone (7)
4 Upright in one US state (2,3)
5 One might flip shilling over which to listen to (6)
6 Cricket match on London train – there may be a reaction here (4,4)
11 Devil allowed in (not talked about) (8)
13 Internally salve Olivia's breathing apparatus (7)
15 Usher cycling with conquistador (6)
17 Damaged golden hardware (6)
18 Hedge sparrow, missing tail? Don't ask me! (5)
21 Pious type who's never out of order (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #231

set by Bethan Ackerley

1 The force exerted on a spinning ball moving through air that causes its path to bend, seen in sports like football, is known as what?

2 Which of the following isn't a cultivar of the species *Brassica oleracea*: turnip, kohlrabi or collard greens?

3 Name the spacecraft that performed the first soft landing on a comet.

4 Which 13th-century polymath is credited as the first person to describe the pulmonary circulation of the blood?

5 How many naturally occurring isotopes of hydrogen are there?

Answers on page 47

Headscratcher

set by Zoe Mensch

#251 Children of Quirkopia

For an inexplicable reason, the population on the island of Quirkopia had always been split 75 per cent male and 25 per cent female. Maybe it is genetic, or maybe it is something in the water. Anyway, the new president of the island believed something should be done about it, so she decided to implement a new family planning policy.

From then on, families were allowed to have as many children as they wanted until they had a boy, at which point they had to stop. There was no obligation to keep having children of course – parents might have two girls and finish there.

Fifty years later, you visit the island's school. As the children filter back into the classroom, what do you notice?

a) They are all boys
b) About three-quarters are boys
c) The class is split roughly 50/50 boys and girls
d) There are more girls than boys

Solution next week

Sound off

A huge amount of sound is generated in the world, which takes energy. As the sound dissipates, what happens to this energy?

Ron Dippold
San Diego, California, US
Sound exists in the form of vibrations, or waves, in the air, which can be easily converted to heat. Heat is molecules vibrating; cold is molecules not vibrating as much. So, simply put, all the world's sound turns into a little bit of heat.

Thankfully, this resultant heat is negligible in terms of global warming: just as you can't usefully heat tea by stirring it, sound can't appreciably heat things up.

Sound energy is weak. An annoyingly loud sound like a train engine or pneumatic drill is just a hundredth of a watt per square metre. Sunlight is 680 watts per square metre, so sunlight is a few hundred thousand times more powerful than the loudest sound.

Basically, all that sound just turns into a tiny, negligible amount of heat. This is little consolation when that dog barks all night long, but at least it isn't contributing to global warming.

"An annoyingly loud sound like a train or a pneumatic drill is just a 100th of a watt per square metre – sound energy is weak"

David Bortin
Whittier, California, US
If a tree falls in the forest and there is no one there to hear it, does it make a sound?

That old riddle pretends to the profundity of a puzzle for physicists or philosophers, but it is actually for semanticists to say whether a "sound" is only what is heard or all the pressure waves of molecules moving through the air. If a sound is only what is heard, then the answer to the question must acknowledge that some portion of the energy from the hearer's vibrating eardrums is converted into the electrical energy of cognition.

If any pressure wave moving through the air counts as sound, those can also be converted into electrical energy, by employing electromagnetic induction or piezoelectric crystals. But in nature, most of this energy (which is already in the form of moving air molecules) becomes molecular vibration, aka heat.

And whence goes that heat in the cool stillness of the forest air? Short answer: every which way. Perhaps some thermal energy might promote the chemical bonding (a form of potential energy) needed to make another tree grow taller and more massive, thus making the sound that much louder when it, too, eventually falls. And we go round and round and round in the circle game.

Eric Kvaalen
Les Essarts le Roi, France
Sounds made indoors echo off the walls and probably mostly get absorbed by furniture and other "viscoelastic" materials, turning the energy into heat.

Sounds made outdoors mostly go into the atmosphere, either because the sound waves start off going somewhat upwards or because they reflect off the ground. Sound that goes downwind, up to a certain angle upwards, will bend (or refract) back down to the ground because of the gradient of wind speed, but sound going upwind will bend upwards, as will sound going downwind above a certain altitude, because of the fact that the speed of sound decreases with altitude. (Sound goes slower in colder air.) This sound won't encounter anything solid.

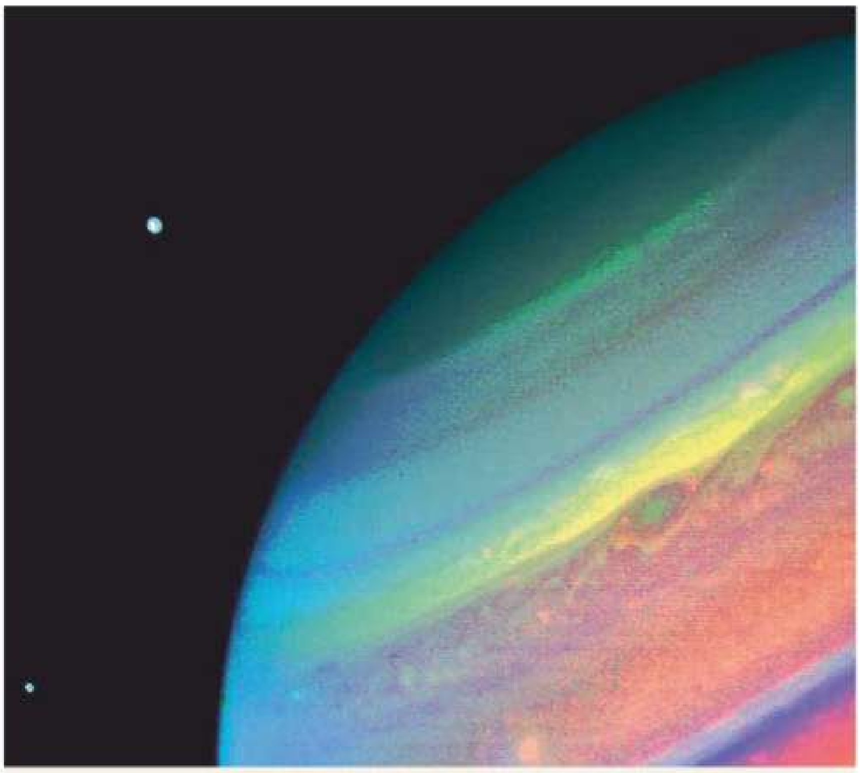
But as they go higher, into more rarefied air, sound waves change. A sound wave consists of pressure variations and velocity variations. The points in the wave where the pressure is high are the points where the air is moving in the direction of propagation, and where the pressure is low, the air moves in the opposite direction.

The ratio between this pressure variation and the speed of the wave is equal to the ratio between the overall pressure and the speed of sound. As the waves go higher, this ratio goes down, because pressure decreases faster than temperature. (In fact, at some altitudes, temperature increases with height.) This means the speed of the air at the wave crests gets greater as the wave goes higher. It is like a wave of the sea coming to the shore – the water moves faster as it gets shallower.

Just as a wave coming to shore will eventually crash, the sound wave becomes a series of shock waves. Since the crests of the waves are moving forward, the speed of sound at the crests is higher than in the troughs, so the shape of the wave changes until it becomes sudden rises followed by gradual declines in both pressure and speed.

Each little shock wave comes upon the backward-moving air molecules in front of it and makes them start moving forward. It is similar to cars piling into a crash on a highway and suddenly changing velocity, while contributing energy to the pile-up. (Here, the shock is moving backwards up the highway.)

This means an increase in entropy and generation of heat. Through this process, a 400-hertz sound wave will


NASA/JPL

Are the Voyager spacecraft ever likely to collide with a planet or star in the far reaches of space?

This week's new questions

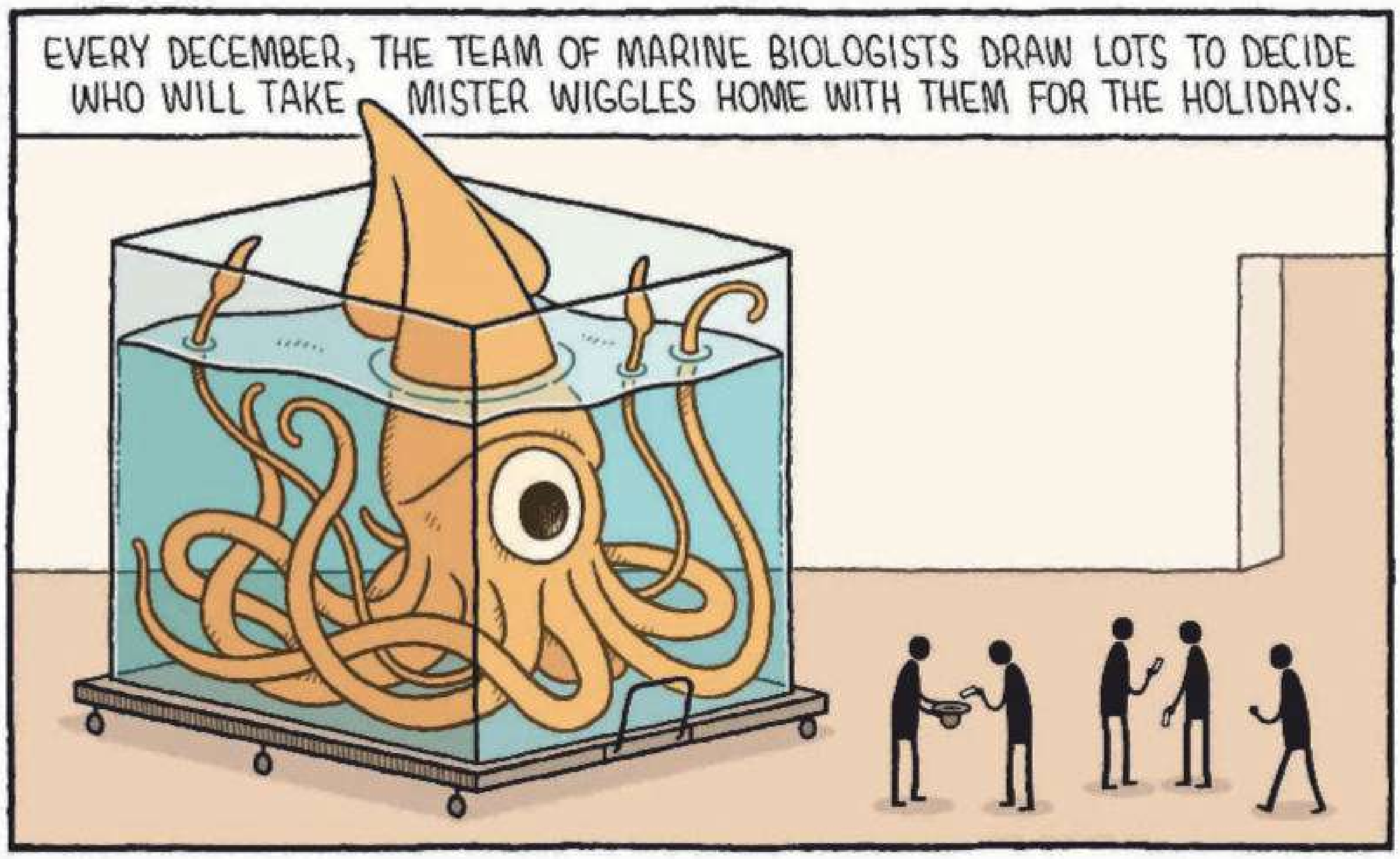
Crash course **If they continue on their current trajectories, what is the probability Voyager 1 or 2 will crash into a planet or star in the (distant) future?** ***Paul Mitchell****, Tregony, Cornwall, UK*

Up and down **Do people who live in hilly towns have better health than those who live in flat towns?** ***Derek Johnson****, Moreton-in-Marsh, Gloucestershire, UK*

Want to send us a question or answer?
Email us at lastword@newscientist.com
Questions should be about everyday science phenomena
Full terms and conditions at newscientist.com/lw-terms

Tom Gauld

for New Scientist


EVERY DECEMBER, THE TEAM OF MARINE BIOLOGISTS DRAW LOTS TO DECIDE WHO WILL TAKE MISTER WIGGLES HOME WITH THEM FOR THE HOLIDAYS.

become 400 tiny shock waves passing any given point per second, each one generating a small amount of heat.

Besides this effect, air has "bulk viscosity", which means that even when there are no shock waves, some of the energy is constantly turning into heat.

Alan Dix
Aberaeron, Ceredigion, UK
As I am sure others will point out, the ultimate end of every word ever spoken is more hot air.

Ready for take-off

Do winged animals like birds ever suffer comparable mishaps to those of human-made aircraft, such as aerodynamic stall, wing icing or hard landing? (continued)

Herman D'Hondt
Sydney, Australia
This question reminded me of the landing technique of two species of birds. The wedge-tailed shearwater, or mutton bird, as it is known in Australia, nests in burrows on Pacific islands. It spends the day catching fish, returning after dark to feed its young. The problem is that it is very dark in the forests where the burrows are. That doesn't deter the mutton bird though. It just flies downwards between the trees until it hits something – hopefully the ground. Then it picks itself up and searches for its burrow.

"The mutton bird isn't deterred by darkness when landing – it just flies down until it hits something, hopefully the ground"

The kākāpō, a flightless parrot, lives in New Zealand. It has been described as "the bird that has forgotten that it has forgotten how to fly". When startled, it often climbs up a tree. Then, when the coast is clear, it launches itself into the air.

One assumes that, shortly before the crash, it thinks, "Oops, I just remembered something..."

Paul Douglas
Wellington, New Zealand
I have been living rough on the outskirts of Wellington for over six and a half years now. I have blackbirds that deliberately make hard landings on my tent roof when they want to be fed. If I don't respond immediately, they will try stomping or fluttering their wings.

John Davies
Lancaster, UK
Birds have evolved consummate control systems for flight in almost all conditions, but landings can catch them out. This is especially true for those that spend all their time above or on the sea, but that must land to breed. Shearwaters choose to land at night to make it even more difficult, while puffins and albatrosses have difficulty making it look easy in the day. Albatrosses also tend to need to take off into the wind. On the other hand, land-based waterfowl can be fooled by ice-covered water, and swans, as others have noted, are notorious for taking a tarmac road to be a convenient river! ▮

Answers

Quick quiz #231

Answers

1 The Magnus effect
2 Turnip
3 Philae
4 Ibn al-Nafis
5 Three

Quick crossword #147 *Answers*

ACROSS 1 Cocoon, **4** Pancreas, **9** Energy, **10** Acanthus, **12** Sciences, **13** Bronze, **15** Telephone box, **18** Cosmologists, **21** Kakapo, **22** Octagons, **24** Bollards, **25** Lipoma, **26** Bessemer, **27** Syzygy

DOWN 1 Creosote, **2** Chenille, **3** Organophosphate, **5** Arch, **6** Centre of gravity, **7** Ethane, **8** System, **11** Megohms, **14** Reflect, **16** Osmology, **17** Isostasy, **19** Skibob, **20** Skulls, **23** Edge

#250 Are we nearly there yet?

Solution

The journey will take a further 16 minutes. Call the first and last digits of the original distance a and b. We know the middle digit was zero, so that distance was a0b. As the speed is constant, the distances covered in the two 45-minute periods must be equal, so that a0b – ba = ba – ab, which gives a0b + ab = 2(ba).

A number written as "a0b" equates to 100a + b and ab to 10a+b. So our equation becomes 100a + b + 10a + b = 20b + 2a. This gives 108a = 18b. Hence b = 6a. Since b is a single digit, it must be 6 and a = 1. The distances were 106, 61 and 16 and, with 45 miles taking 45 minutes, the final 16 miles take 16 minutes.

Gearing up for happiness

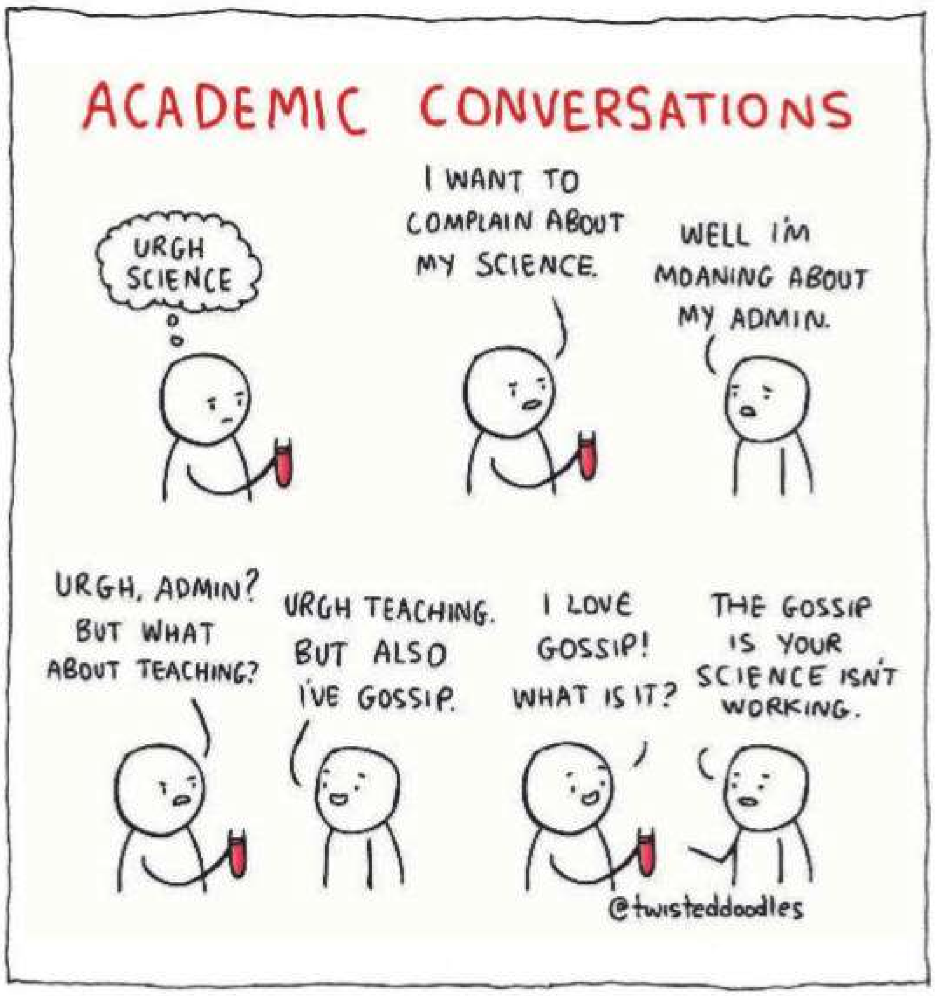
Transitions sometimes start with a period of frustration. People can adapt to new ways – but the old ways are familiar, which make them feel comfortable in comparison with the new. Transmissions, too, sometimes start with a period of frustration. Tim Stevens reports in *Ars Technica* about how one automobile manufacturer is solving a problem some of its customers have in transitioning from a petrol-powered car to an electric vehicle (EV).

The news headline says it all: "Toyota has built an EV with a fake transmission, and we've driven it – Five minutes behind the wheel, and you'll be a believer."

This is for customers who love the ancient experience of driving with a gearstick. Toyota's new car has a joystick and a clutch pedal. Neither is connected to the car's actual transmission. Stevens writes: "something strange happens: An engine fires up. It's a pretend one, exhaust humming only through the car's sound system. Still, it sounds compelling enough. Step on the throttle pedal, and that pretend engine gains revs, screaming up to its limiter with simulated aggression. To be clear: Literally nothing is happening in the car at this point other than the sound changing pitch. Oddly, though, something was happening in me: I was smiling. For no logical reason, I suddenly was having a lot more fun."

Feedback marvels at this new techno-twist on the old philosophical drive to answer the question "What is reality?"

Twisteddoodles *for New Scientist*


ACADEMIC CONVERSATIONS
URGH SCIENCE
I WANT TO COMPLAIN ABOUT MY SCIENCE.
WELL I'M MOANING ABOUT MY ADMIN.
URGH, ADMIN? BUT WHAT ABOUT TEACHING?
URGH TEACHING. BUT ALSO I'VE GOSSIP.
I LOVE GOSSIP! WHAT IS IT?
THE GOSSIP IS YOUR SCIENCE ISN'T WORKING.
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

A stink about beer

Beer enthusiast Bernd-Juergen Fischer of Berlin is peeved. He tells Feedback: "Your paragraph on beer foam aroma sceptics [21 October] set my head spinning: 'if there are any'! And this in a journal out of Britain, where the greatest care is being taken by tappers to remove even the last vestige of foam off the beer before a-spilling it onto the table! When I complained to a publican about it, he responded: 'If you want a tasty beer, you can always go to the continent.'

"My wife then explained to me what every child in the Anglo-Saxon world seems to know: 'The Brits like only what they dislike: take broccoli. Or the EU: when they began to like it, they left it.' This explains also why you had to leave such in-depth beer-foam research to the Japanese: There ain't any in GB."

Bernd-Juergen might persuade publicans by giving them copies of a Mexican study, "Productivity in the use of beer foam". It suggests how to "make the foam more attractive to the consumer".

Medical amusement

An old saying, iffily attributed to Voltaire, explains that "the art of medicine consists mostly of amusing the patient while nature cures the disease".

Feedback invites any reader who is a practising, licensed physician to say whether – in your professional experience – that is substantially true. Send your note, accompanied perhaps by a few words of personal professional recollection, to "Medical Amusement", c/o Feedback. Please, for context, identify your own branch of medicine (family doctor, surgeon, cardiologist, neurologist, otolaryngologist, whatever).

Future for ducks

The future arrives faster than one expects. Or slower, depending on one's expectation.

Consider the recent study called "Machine learning approach for Muscovy duck (*Cairina moschata*) semen quality assessment". One hundred years ago, this paper, had it existed, might have been regarded as science fiction.

Desislava Abadjieva, its lead author, is based at the department of immunoneuroendocrinology at the Bulgarian Academy of Sciences' Institute of Biology and Immunology of Reproduction.

Immunoneuroendocrinology! A 1992 report spoke to the then future of a pursuit that, at the time, was little known. It said: "The numerous interactions between the immune and neuroendocrine systems are being studied in a rapidly expanding interdisciplinary field called 'immunoneuroendocrinology'."

During the 31 years since, the entire scientific community, worldwide, has published only about 40 papers that even mention the word immunoneuroendocrinology.

As to the future for Muscovy ducks, a new Brazilian report on its face implies bad news. It is called "Consumption of Muscovy duck eggs by brown capuchin monkeys in a peri-urban forest in the Amazon". The details, though, give a helter-skelter view of what might happen.

What is currently bad news for the ducks could lead to catastrophically worse news, instead, for the monkeys. The report is a stark warning to any brown capuchin monkey who might find a way to read it – and a source of at least some hope for readers who are Muscovy ducks. It explains that, by preying on the ducks, the monkeys might bring on "retaliation" by the humans who traditionally raise and devour those ducks.

This is nature again displaying the give and take that Stephen Sondheim celebrated in a song in his play *Sweeney Todd: The demon barber of Fleet Street*. "The history of the world, my sweet," explains the title character as they cook up how to cook up some pies made of human meat, "is who gets eaten and who gets to eat."

Marc Abrahams

GIVE THE JOY OF DISCOVERY THIS CHRISTMAS...

Screen-Free Fun For Ages 7-14

BRITANNICA'S
What on Earth! MAGAZINE
SPY GA
BRITANNICA'S ENCYCLOPEDIA INFOGRAPHICA
SAVE OVER 15% + FREE BOOK WORTH £25

A subscription to What on Earth! Magazine makes the perfect gift

It's the fun and fascinating way to get children to fall in love with reading and learning – and to get them off their screens!

- Save over 15%
- From just ~~£29.99~~ £24.99 – choose a 6-month or annual subscription
- Get a FREE Britannica Kids' Encyclopedia worth £25 to give on Christmas Day*
- Have the magazine delivered to your child every month
- Amazing facts, photos, jokes, puzzles and games!
- All their favourite topics: animals, space, nature, art, sport, history, inventions and much, much more!

'I love it! There's something amazing on every page.'

ROBIN, AGE 8

Order by 15th December to receive your book by Christmas

Subscribe from just ~~£29.99~~ £24.99 and get a FREE Britannica Children's Encyclopedia worth £25!

3 easy ways to order: www.whatonearth.co.uk/ns16

• Call 01732 464621 and quote NS Offer • Scan the QR code

*Magazines will start to arrive after Christmas. 5 issues in a 6-month subscription and 10 issues in a 12-month subscription. See website for full terms and conditions.

omegawatches.com

AN INCOMPARABLE CREATION

Inspired by a long tradition of bronze craftsmanship at sea, OMEGA has used advanced technology to create the revolutionary Bronze Gold alloy. Featuring a soft pink hue, as well as incomparable corrosion resistance, this unique material offers the warm aesthetic of bronze and the luxurious inclusion of gold. The striking patina has been designed to last through time, and has been paired in this Seamaster 300 model with a dial in aged bronze, and a brown ceramic bezel ring with its diving scale in vintage Super-LumiNova.

Ω
OMEGA